Fishery Data Series No. 05-07

Eastern North Slope Dolly Varden Stock Assessment

by
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Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA REPORT NO. 05-07

EASTERN NORTH SLOPE DOLLY VARDEN STOCK ASSESSMENT

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The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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ABSTRACT

Replicate aerial surveys were conducted concurrently with mark-recapture abundance estimates of the overwintering aggregation of Dolly Varden *Salvelinus malma* in a 28-km index section of the Ivishak River in northern Alaska. Five replicate aerial counts (conducted by two observers from a helicopter) and a mark-recapture abundance experiment were conducted during September of three consecutive years. Aerial surveys were internally precise, with standard errors for each year ranging from 2.8% to 6.7% of the mean summed count. Aerial survey counts represented between 22% and 25% of abundance as estimated by mark-recapture methods. Estimated abundance decreased during the three years of the study, falling from 49,523 fish in 2001 (SE = 7,277) to 21,634 fish in 2002 (SE = 3,075), and to 9,259 fish in 2003 (SE = 1,156). However, the abundance estimate for 2003 could only be conducted in the upper two sections (~20 km) of the index area due to inclement weather, and so is not directly comparable to the 2001 and 2002 estimates. Spawning locations were identified and mapped in the Kongakut, Ivishak, Echooka, Kavik, Ribdon, Lupine, Saviukviayak, and Anaktuvuk rivers. Overwintering locations were identified by radiotelemetry in the Ivishak and Anaktuvuk rivers. Results indicated that the timing and location of spawning is highly variable among years, and that the proportion of the overwintering population spawning each year is highly variable. Overwintering fish used a large amount of a given drainage, and overwintering locations varied among years.

Key words: abundance, aerial surveys, Anaktuvuk River, Dolly Varden, Echooka River, Ivishak River, Kavik River, Kongakut River, Lupine River, mark-recapture, North Slope, overwintering locations, radiotelemetry, Ribdon River, *Salvelinus malma,* Saviukviayak River, spawning locations.

INTRODUCTION

Anadromous Dolly Varden *Salvelinus malma* are widely distributed in the Beaufort Sea drainages of the North Slope of the Brooks Range to the west of, and including, the Colville River (Figure 1). Although Dolly Varden have been documented in many drainages in this area, much of that documentation is limited to presence or absence in a given drainage, while the extent of distribution within each drainage is only partially known. During the summer, adult fish are distributed quite widely in the nearshore-waters of the Beaufort Sea, and they may travel significant distances from their natal or overwintering drainages.

The life history and movement patterns of Dolly Varden are complex (DeCicco 1985, 1989, 1992, 1997; Craig 1977; Morrow 1980). Adults spawn in fresh water, and their progeny rear in freshwater until they are 3-5 years old. They then migrate to the ocean, and from that age on, spend summers in the ocean feeding, but return to fresh water to overwinter, regardless of whether they spawn that year.

Spawning occurs from mid-July through early October, and adults do not typically appear to spawn in consecutive years (Yoshihara 1973). The timing of spawning is variable, and many drainages appear to contain stocks that spawn in late summer (late July through late August) or late fall (late September through mid October). Adults may overwinter in drainages other than their natal drainage, but most return to their natal drainage for spawning (Reynolds 1997; Furniss 1975). Genetic studies of anadromous Dolly Varden from North Slope drainages (Everett et al. 1997; Krueger et al. 1999) indicated that there are distinct genetic differences among spawning stocks from individual drainages or groups of drainages.

Because of the severe winter conditions that occur at these latitudes, Dolly Varden populations are dependant on spawning and overwintering habitat that is probably limited (Craig 1989; Krueger 1999). However, this habitat has not been well cataloged. Documented spawning areas are normally associated with spring or upwelling areas within the floodplain. Overwintering areas are associated with deep pools and with upwelling areas within the floodplain.

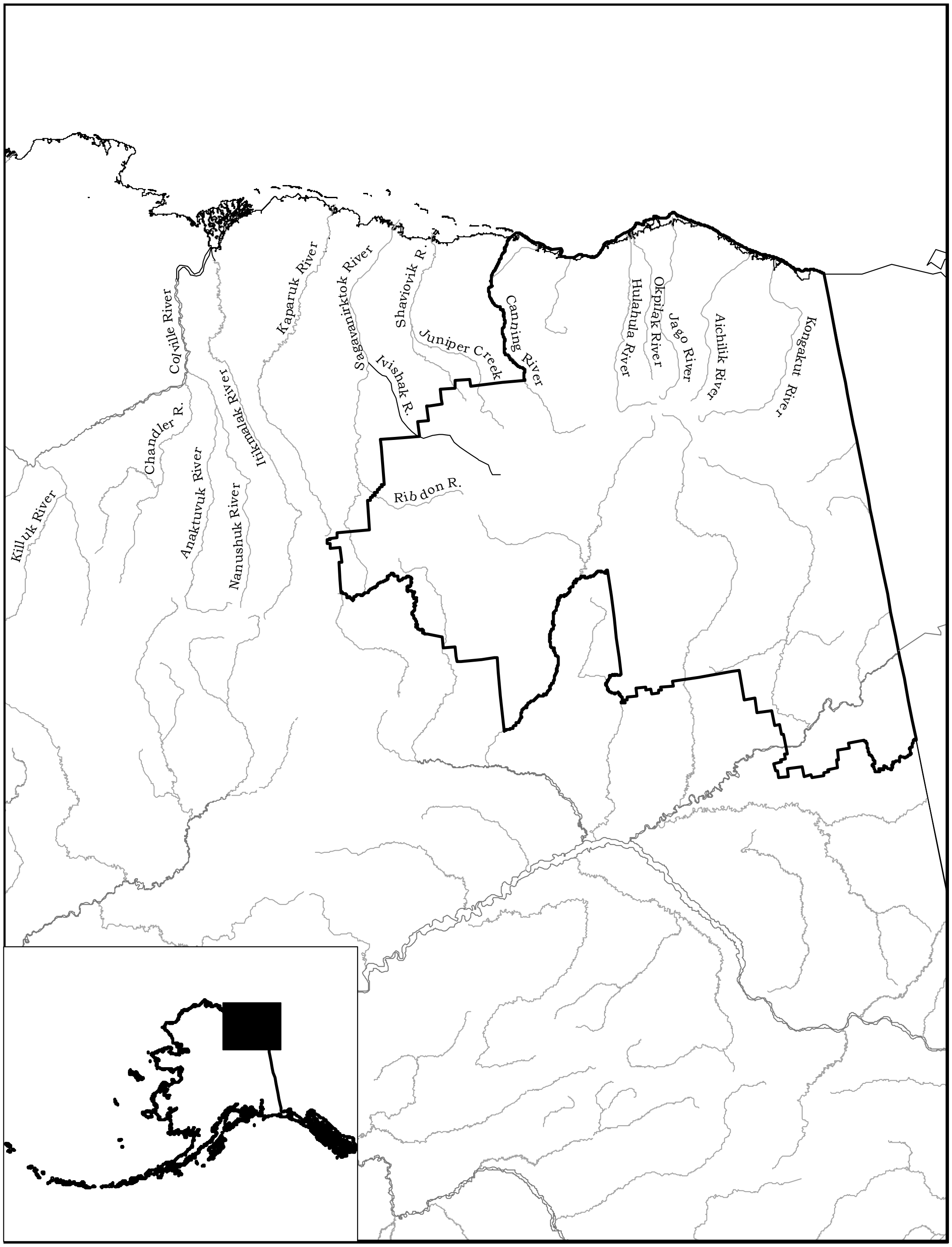

Figure 1.–Map of the eastern North Slope of the Brooks Range and coastal plain showing major drainages containing anadromous Dolly Varden and the boundary of the Arctic National Wildlife Refuge.

Dolly Varden stocks are harvested in subsistence fisheries by residents of Kaktovik, Nuiqsut, Barrow, and Anaktuvuk Pass (Craig 1987; Pedersen 1990). This species is an important component of the subsistence diet in many areas, and in Kaktovik, Dolly Varden harvests represent up to 40% of the total subsistence fish harvest (Pedersen 1990). Dolly Varden are also important to sport fisheries on the North Slope. Average yearly harvests were 1,069 fish and average catches were 5,235 fish for the North Slope during 1992-2001 (Burr 2004).

Previous research on Dolly Varden has focused on providing life history and distribution information (Yoshihara 1972, 1973; Furniss 1975; Craig 1977 and 1989; McCart 1980; Bendock 1980, 1982, 1983; Bendock and Burr 1984; Underwood et al. 1996). Little information is available on abundance or age and size composition of stocks. Abundance information is limited to counts from aerial surveys of several overwintering areas on the Anaktuvuk, Ivishak, and Kongakut rivers (Table 1). To determine whether these surveys provide consistent indices of abundance, the repeatability and relationship of counts to actual abundance must be determined.

Table 1.–Aerial estimates of Arctic char from the Ivishak, Anaktuvuk, and Kongakut rivers of the North Slope[a].

Year	Date	Ivishak River	Anaktuvuk River	Kongakut River	Survey Aircraft	Survey Rating	Data Source
1971	22-Sept.	24,470			H	Good	Yoshihara 1972
1972	24-Sept.	11,937			H	Good	Yoshihara 1973
1973	11-Sept.	8,992			H	Excellent	Furniss 1975
1974	10-Sept.	11,000			H	Not Rated	Furniss 1975
1975	22-Sept.	8,306			H	Not Rated	Bendock ADFG files
1976	22-Sept.	8,570			H	Fair	Bendock ADFG files
1979	22-Sept.	24,403	15,717		FW	Excellent	Bendock 1980
1981	22-Sept.	24,873	10,536		FW	Excellent	Bendock 1982
1982	22-Sept.	36,432	6,222		FW	Excellent	Bendock 1983
1983	22-Sept.	27,820	8,743		FW	Excellent	Bendock and Burr 1984
1984	22-Sept.	24,818	5,462		FW	Excellent	Bendock and Burr 1985
1986	No survey			8,900		Not Rated	Millard USFWS files
1989	22-Sept.	12,650		6,355	H	Good	DeCicco ADFG files
1993	3-Sept.	3,057			H	Good	Millard USFWS files
1995	27-Sept.	27,036		14,080	H	Good	Burr ADFG files

[a] No surveys were done for years not listed. Survey aircraft was either a helicopter (H) or fixed wind aircraft (FW: Piper Super Cub).

Dolly Varden are a critical component of North Slope ecosystems, they support both subsistence and sport fisheries, contribute marine-derived nutrients to low productivity aquatic food webs, and provide food for avian and mammalian predators. Dolly Varden stocks depend on habitats which are limited and located in areas that have a high potential for nonrenewable resource exploration and development.

At present, harvests in sport and subsistence fisheries appear to be sustainable and habitat is generally intact. However, if harvests increase or habitat is degraded, abundance information for major overwintering aggregations as well as for spawning stocks will be needed to assess the status of populations. Information on both spawning and nonspawning components is needed to accurately assess population status because the numbers of fish that return to overwintering locations varies greatly among years and mature fish may not spawn every year. Estimates of the stock composition of harvests and overwintering aggregations will also be needed to track the status of specific stocks. Finally, because Dolly Varden populations depend on specific types of habitat for rearing, spawning, and overwintering, sustainability of these stocks also depends on documenting the locations of critical habitat.

The migration timing and overwintering distribution of Dolly Varden make traditional mark-recapture or escapement-type abundance estimation of populations difficult and expensive to conduct. Aerial surveys of established index areas would be the most cost effective method of conducting repeated (over time) assessments of these stocks, but the variability of the method has not been fully determined, and the relationship of aerial survey estimates to total abundance has not been established.

There have been a number of studies on subsistence fisheries that utilize these stocks (Craig 1987; Pedersen et al. 1985; Jacobson and Wentworth 1982). However, harvest information is limited (Pedersen 1990), and stock composition of harvests is unknown. If there is sufficient genetic differentiation between stocks, relative contribution of different stocks to harvests could be estimated by comparing genetic samples from fin clips of harvested fish to a genetic baseline of the major spawning stocks that contribute to these fisheries.

This project on the Ivishak River, a major tributary of the Sagavanirktok River, was chosen because it contains the largest known overwintering aggregation of Dolly Varden on the North Slope and has similar characteristics to most other North Slope drainages. The Ivishak River flows about 145 km from its headwaters in the Arctic National Wildlife Refuge to the Beaufort Sea. It contains a number of springs in its headwaters, large groundwater upwelling areas in the lower braided floodplain, and large, semi-permanent ice fields.

This project estimated the precision of replicate aerial surveys of the overwintering aggregation of Dolly Varden in the Ivishak River, and examined the relationship between aerial survey abundance estimates and mark-recapture abundance estimates of the same overwintering aggregation. Both estimation procedures were conducted for three consecutive years. The project also collected data to catalog and map critical spawning and overwintering habitat. In addition, stock-specific genetic samples were obtained from nine major spawning stocks that contribute to subsistence fisheries, and a mixed stock genetic sample was obtained from the overwintering aggregation in the Ivishak River. The genetics component of this study will be addressed in a separate report (Crane *In prep*).

OBJECTIVES

Specific objectives of this study were:

1) Estimate the variability of replicate aerial surveys of the overwintering aggregation (within a fixed 25 km area) on the Ivishak River conducted by the same observers under similar conditions during the same time period during each of three years.
2) Estimate the abundance and size composition of Dolly Varden in the overwintering aggregation (same geographic area as objective 1) on the Ivishak River such that the abundance estimate is within 20% of the true value 90% of the time during each of three years.
3) Identify new and verify known spawning locations on the Kongakut, Ivishak, Echooka, Anaktuvuk, Hulahula, Canning, Aichilik, Marsh Fork, Kavik, and Saviukviayak rivers and collect GIS mapping data for all verified and new locations.
4) Identify new and verify known overwintering locations on the Ivishak and Anaktuvuk rivers and collect GIS mapping data for all verified and new locations such that the power to detect up to five overwintering locations comprising 100% of the locations used is at least 95%.

METHODS

STUDY AREA

To facilitate comparison of mark-recapture estimates and aerial survey counts, both between years and between methods, all counts and mark-recapture studies were conducted within a 28 km index area of the Ivishak River established during the first year of study (Figure 2). This index area was established based on initial aerial surveys that indicated most (over 90%) non-spawning overwintering Dolly Varden present in the river by mid-September were within this area. The index area was divided into three equal length sections to evaluate movement of marked fish during abundance estimation. In portions of the index area where multiple channels existed, the channel in which the most fish were present was marked (with fluorescent stakes near the water's edge). All subsequent aerial surveys and attempts to capture fish for mark-recapture estimates were restricted to those marked channels.

AERIAL SURVEY VARIABILITY ESTIMATION

Five replicate aerial surveys of the index area were conducted between September 18 and 23 during 2001 and 2002. Six replicate surveys were conducted between September 17 and 23 in 2003, but results of one survey were excluded from analysis because it was conducted under marginal viewing conditions. Counting was conducted from a helicopter by two observers (same observers in all years), each counting only the fish present on one side of the river. Surveys were flown beginning at the upstream end of the index area, at an altitude of approximately 50 m, and a ground speed of approximately 40 km/hr. Each observer counted the same side of the river during each survey. Although all channels were not counted, the same marked channels were counted during each survey. During each surveys, counts were subtotaled for each section prior to counting the next section.

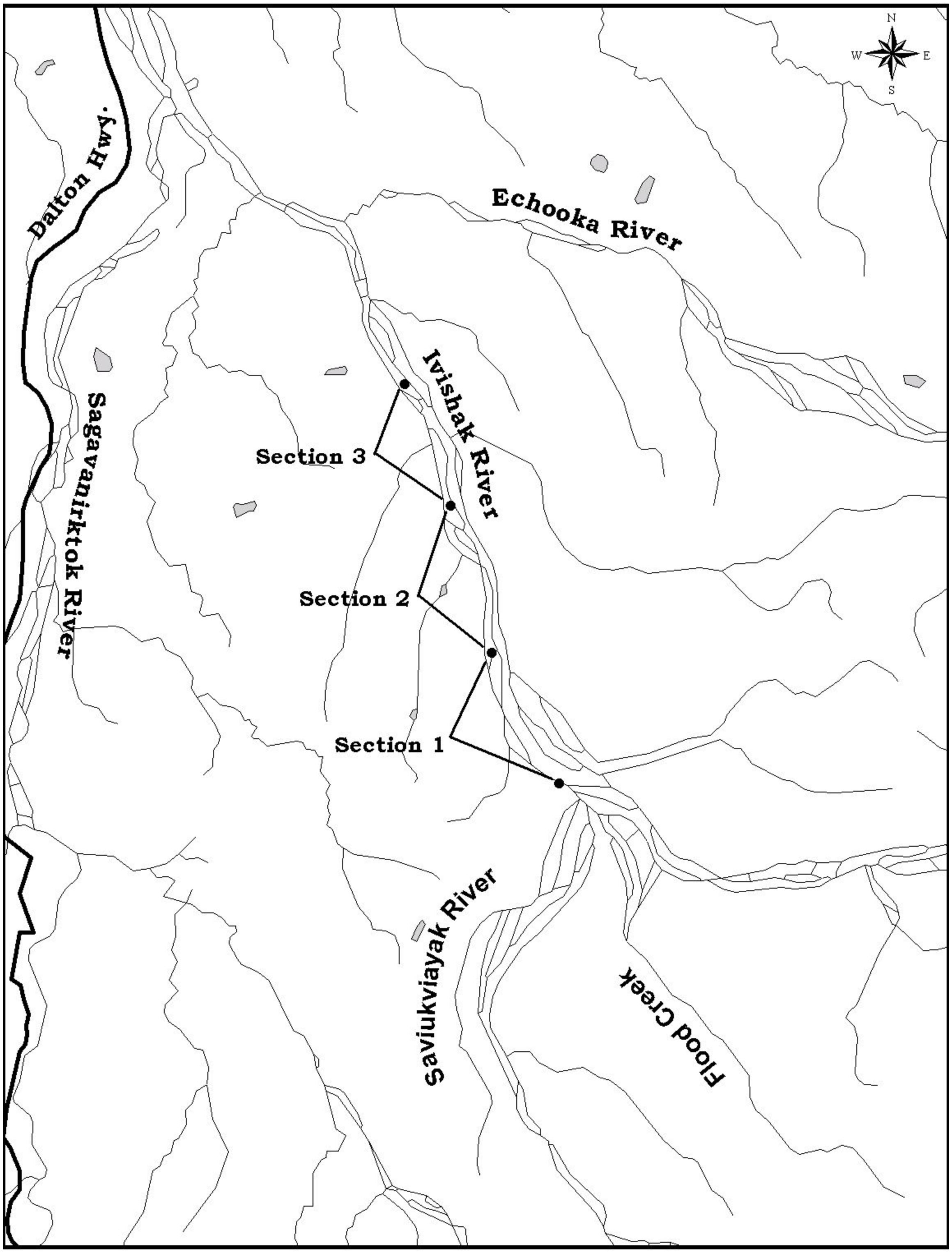

Figure 2.–Map of the Ivishak River, Alaska, showing the boundaries of the 28-km index area.

Replicate counts were made after Dolly Varden upriver migration was judged to be complete. The migration was judged to be complete after aerial surveys conducted within and below the index area indicated less than 10% of the total number of Dolly Varden counted were present in the 10 km reach of river immediately below the 28-km index area. To eliminate conscious or unconscious bias during counts, replicate counts were conducted with the face plates of the counting devices covered, and the totals were recorded by the helicopter pilot and the forms containing individual section and total daily counts were not made available to the observers until all replicate surveys (from each year) were completed.

MARK-RECAPTURE ABUNDANCE ESTIMATION

A mark-recapture abundance estimate of the overwintering population within the 28 km index area was conducted each year using a Bailey-modified Petersen two-event estimation procedure (Seber 1982). Adult fish were captured using beach seines, measured, and marked with a small partial fin-clip and an operculum punch. In areas with multiple channels, the mark-recapture estimate was conducted in the same marked channels identified and counted during aerial survey counts. Fish were marked during a seven day period, and were recaptured by a second crew after a hiatus of at least two days, to allow for mixing of marked and unmarked fish.

In order to evaluate fish movement during the experiment, the 28-km index area was divided into three approximately equal sections prior to the marking event. During the marking event, fish captured in each section were given different fin clips to evaluate movement among sections during the experiment. Length, date, fin clip, and section were recorded for each fish captured. Data from the mark-recapture portion of the study was recorded on mark-sense forms. All Dolly Varden captured were measured to the nearest 5 mm from snout to tail fork (FL). The assumptions necessary for an accurate estimate of abundance were (taken from Seber 1982):

1. the population was closed (no change in the number or size of Dolly Varden in the population during the experiment);
2. all Dolly Varden had the same probability of capture during the marking event or in the recapture event, or marked and unmarked fish mixed completely between marking and recapture events;
3. marking of Dolly Varden did not affect their probability of capture in the recapture event;
4. Dolly Varden did not lose their mark between the marking and recapture events; and,
5. all marked Dolly Varden were reported when recovered in the recapture event.

Sampling was designed so that overall study duration and hiatus between events were short to lessen risks associated with assumption 1. The studies were completed in less than 15 days which reduced the likelihood of natural mortality. The likelihood of immigration into the study area could not be totally precluded, particularly with fall-run Dolly Varden. However, the experiments were not begun until after aerial surveys indicated that there were few fish below the assessed area, which indicated the migration upstream was complete. This assumption was also partially examined through comparison of the marked-to-unmarked ratios in the lowermost sampled area (subject to immigration from downstream areas), and examination of daily catch patterns relative to the upstream and downstream sampling locations. Additionally, evaluation of movement patterns of radio-tagged fish (described below) was also used to assess the validity of this assumption. The estimator allowed for immigration to occur between sampling events, but if it occurred, made the abundance estimate germane to the time of the second (recapture) event.

The hypotheses that the probability that a fish was captured during the marking or recapture events was independent of the size of the fish (assumption 2) were tested using two Kolmogorov-Smirnov two-sample tests. There were four possible outcomes of these tests: either one or both of the samples were biased or neither was biased. Possible actions for estimating abundance and length composition depending on the outcomes of these tests are outlined in Table 2.

Table 2.-Methodologies for alleviating bias due to size selectivity by means of statistical inference.

	Result of first K-S test [a]	Result of second K-S test [b]
Case I [c]		
	Fail to reject H_o	Fail to reject H_o
	Inferred cause: There is no size-selectivity during either sampling event.	
Case II [d]		
	Fail to reject H_o	Reject H_o
	Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event.	
Case III [e]		
	Reject H_o	Fail to reject H_o
	Inferred cause: There is size-selectivity during both sampling events.	
Case IV [f]		
	Reject H_o	Reject H_o
	Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H° for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H° for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Estimate length and age distributions from second event and adjust these estimates for differential capture probabilities.

Because capture probabilities could potentially differ between sections, assumption 2 was also examined using the three tests of consistency described by Seber (1982). If one of the three tests was not significant, then at least one of the conditions in assumption 2 was satisfied and an unstratified (geographically) Bailey-modified Petersen estimator was used to estimate abundance. If there was movement between sections, but all three of the consistency tests were significant, a partially stratified Darroch (1961) estimator was appropriate. If no movement between sections of the index area occurred and all these tests were significant, a geographically stratified Bailey-modified Petersen estimate was appropriate (Seber 1982).

The last three assumptions were assumed to have been satisfied by the field procedures used during sampling. Assumption 3 was thought to be met because the active nature of the gear minimized the chance of gear-induced changes in capture probability. Assumption 4 was met because all fish were marked by a partial finclip that could not grow back during the study period. Assumption 5 was thought to be met because a secondary mark was placed on the operculum of all marked fish and field personnel carefully examined all fish for marks.

The modified Petersen estimator of Bailey (1951, 1952) was used to estimate abundance:

$$\hat{N} = \frac{n_1(n_2+1)}{(m_2+1)} \tag{1}$$

where:

$\hat{N}$ = abundance of Dolly Varden in the Ivishak River study area;

n_1= number of Dolly Varden marked and released during the first event;

n_2= number of Dolly Varden examined for marks during the second event; and,

m_2= number of Dolly Varden recaptured in the second event.

Variance of this estimator is provided by (Bailey 1951, 1952):

$$V[\hat{N}] = \frac{(n_1)^2(n_2+1)(n_2-m_2)}{(m_2+1)^2(m_2+2)}. \tag{2}$$

Sample sizes were determined according to procedures outlined by Robson and Regier (1964). The sample sizes for each year's mark-recapture experiment were determined according to Table 3, depending roughly on the number of fish counted in the index area during initial aerial surveys. Assuming that aerial surveys typically underestimated the number of fish present in the assessed areas, the population size used was assumed to be approximately five times higher than the number counted during the initial aerial survey immediately preceding the marking event. Attempts were made to apportion the total sample size for each event among each of the three sub-sections according to the relative abundance within each section observed during aerial surveys.

Table 3.–Sample sizes needed to meet objective criteria for abundance estimate of spawning/overwintering aggregation within the Ivishak River (Robson and Regier 1964).

Aerial survey count just prior to marking event is within		Assumed population size	Number to mark during 1st event	Number to examine for marks during 2nd event	Population marked or examined during the 2nd events	Expected number of recaptured fish during 2nd event	Expected number of unique fish examined
55	166	500	136	136	27.2	37	235
167	277	1,000	209	209	20.9	44	374
278	388	1,500	266	266	17.7	47	485
389	499	2,000	315	315	15.8	50	580
500	832	2,500	358	358	14.3	51	665
833	1,388	5,000	529	529	10.6	56	1,002
1,389	1,943	7,500	660	660	8.8	58	1,262
1,944	2,499	10,000	771	771	7.7	59	1,483
2,500	3,055	12,500	869	869	7.0	60	1,678
3,056	3,610	15,000	958	958	6.4	61	1,855
3,611	4,166	17,500	1,040	1,040	5.9	62	2,018
4,167	4,721	20,000	1,116	1,116	5.6	62	2,170
4,722	5,277	22,500	1,187	1,187	5.3	63	2,311
5,278	6,110	25,000	1,255	1,255	5.0	63	2,447
6,111	7,221	30,000	1,381	1,381	4.6	64	2,698
7,222	8,332	35,000	1,497	1,497	4.3	64	2,930
8,333	9,443	40,000	1,604	1,604	4.0	64	3,144
9,444	10,555	45,000	1,706	1,706	3.8	65	3,347
10,556	11,666	50,000	1,801	1,801	3.6	65	3,537
11,667	12,777	55,000	1,892	1,892	3.4	65	3,719
12,778	13,888	60,000	1,979	1,979	3.3	65	3,893
13,889	14,499	65,000	2,063	2,063	3.2	65	4,061
15,000	17,778	70,000	2,143	2,143	3.1	66	4,220

LENGTH COMPOSITION IN MARK-RECAPTURE ASSESSMENT

Procedures for testing assumptions necessary for accurate abundance estimation were also used to detect potential biases in length composition samples. Length information was used to apportion the population estimate into length classes; and length information collected during the marking event, the recapture event, or both events combined was used to calculate length composition, depending on the outcome of the tests described in Table 2.

If no size selectivity was detected during either event (case 1), no adjustments to length data were necessary and data from both events were pooled. If size selectivity was detected only during the marking event (case II), only length data from the recapture event was used to estimate length composition. For these two scenarios, the proportion of fish at length was calculated as:

$$\hat{p}_k = \frac{n_k}{n} \tag{3}$$

where:

$\hat{p}_k$ = the proportion of Dolly Varden that were within length class k;

n_k = the number of Dolly Varden sampled that were within length class k; and,

n = the total number of trout sampled.

The variance of this proportion was estimated as (Cochran 1977):

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1} \tag{4}$$

If size selectivity was detected during both events (case III), or if size selectivity was detected during the recapture event and the status during the marking event was not known (case IV), length data were grouped into size strata with similar probabilities of capture within strata from one or both samples. Diagnostic tests for size selectivity (Table 2) were then conducted within strata, and results of these tests were used to determine if length data from one or both samples could be used to estimate composition within these strata. Unbiased composition estimates were calculated after adjusting for differing probabilities of capture using abundances estimated by size strata. To adjust length data, the proportion of fish in each length class was calculated by summing independent abundances for each length class and then dividing by the summed abundances for all length classes. First the conditional proportions from the sample were calculated:

$$\hat{p}_{ik} = {}^{n_{ik}}\!/_{n_i} \tag{5}$$

where:

n_i = the number sampled from size strata i in the mark-recapture experiment;

n_{ik} = the number sampled from length class k that are within size strata i; and,

$\hat{p}_{ik}$ = the estimated proportion of fish in length class k within size strata i.

The variance calculation for $\hat{p}_{ik}$ was identical to equation 4 (with appropriate substitutions).

If stratification was necessary, length class proportions for Dolly Varden were estimated using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik} \tag{6}$$

The variance of $\hat{p}_k$ was approximated using the Delta method (Seber 1982) by:

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^{j} (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_{i=1}^{j} \left(\frac{\hat{N}_i}{\hat{N}}\right)^2 \hat{V}[\hat{p}_{ik}] \tag{7}$$

where: $\hat{N}_i$ = the abundance of Dolly Varden in size stratum i; and,

$\hat{N}$ = total abundance of Dolly Varden.

RADIOTELEMETRY/OVERWINTERING LOCATIONS

Dolly Varden were surgically implanted with standard (not encoded) Advanced Telemetry Systems (ATS) internal radio tags, with frequencies spaced approximately every 10 kHz in the 148 – 151 mHz frequency range. Radio-tags were inserted into the body cavity through a ~15 mm incision on the ventral surface of the belly, approximately 4 cm anterior of the pelvic girdle. The antenna of the tag was then threaded through a second ~2-3 mm incision just posterior to the pelvic girdle. The main incision was sutured with 4 -5 stitches using 3.0 Ethicon monofilament sutures. Antennae incisions were closed with veterinary-grade isocyanurate (Vet-Bond)

After implantation, fish were held for 30 minutes to ensure complete recovery from surgery and anesthesia. Post-implant locations were determined using a helicopter equipped with dual, switched, two-element H antennae and ATS Model R-4000 receivers. During all radio tracking, GPS coordinates (latitude/longitude) were recorded for all fish located.

Forty Dolly Varden were implanted with radio tags in the Ivishak River on September 14-16, 2001 to evaluate movement during the mark-recapture experiment and to identify specific overwintering sites during April, 2002. Ten non-spawning fish were tagged near the lower end of each of the two upper sections of the 28-km index area, 11 non-spawning fish were tagged near the lower end of the lowest section of the 28-km index area, three non-spawning fish were tagged about 4-km below the bottom of the index area, and three pre-spawning fish were tagged in the both the upper Saviukviayak River and the upper Ivishak River (Figure 3). Aerial surveys were flown to locate radio-tagged non-spawning fish on September 17, 20, and 23, 2001, to evaluate fish movement during the mark-recapture experiment, and during April 2002, to identify overwintering locations. Radio-tagged pre-spawners were not located during September, 2001, but their frequencies were monitored within the index area on September 17, 20, and 23 to ensure that spawning fish were not moving into the index area from upstream.

Forty non-spawning Dolly Varden were also implanted with radio tags in the Ivishak River on September 14-16, 2002 to evaluate fish movement during the mark-recapture abundance estimate and to identify specific overwintering sites during April 2003. Ten non-spawning fish were tagged at the lower end of each of the three sections of the 28-km index area, and 10 non-spawning fish were tagged just below the upstream end of the top section (Figure 4). Surveys were flown to locate radio-tagged fish on September 19, 22, and 24, 2002, to evaluate fish movement during the mark-recapture experiment, and on April 25, 2003, to identify overwintering locations.

Twenty-two non-spawning Dolly Varden were implanted with radio tags on the Anaktuvuk River on September 19, 2003, in order to identify specific overwintering locations during April, 2004 (Figure 5). Originally, 40 radio tags were to be implanted, but deteriorating weather conditions prevented completion of this task on September 19, and a combination of weather and helicopter problems prevented any further opportunities to return to the Anaktuvuk River to implant the remaining 18 radio tags. Therefore, all remaining 18 radio tags were implanted into pre-

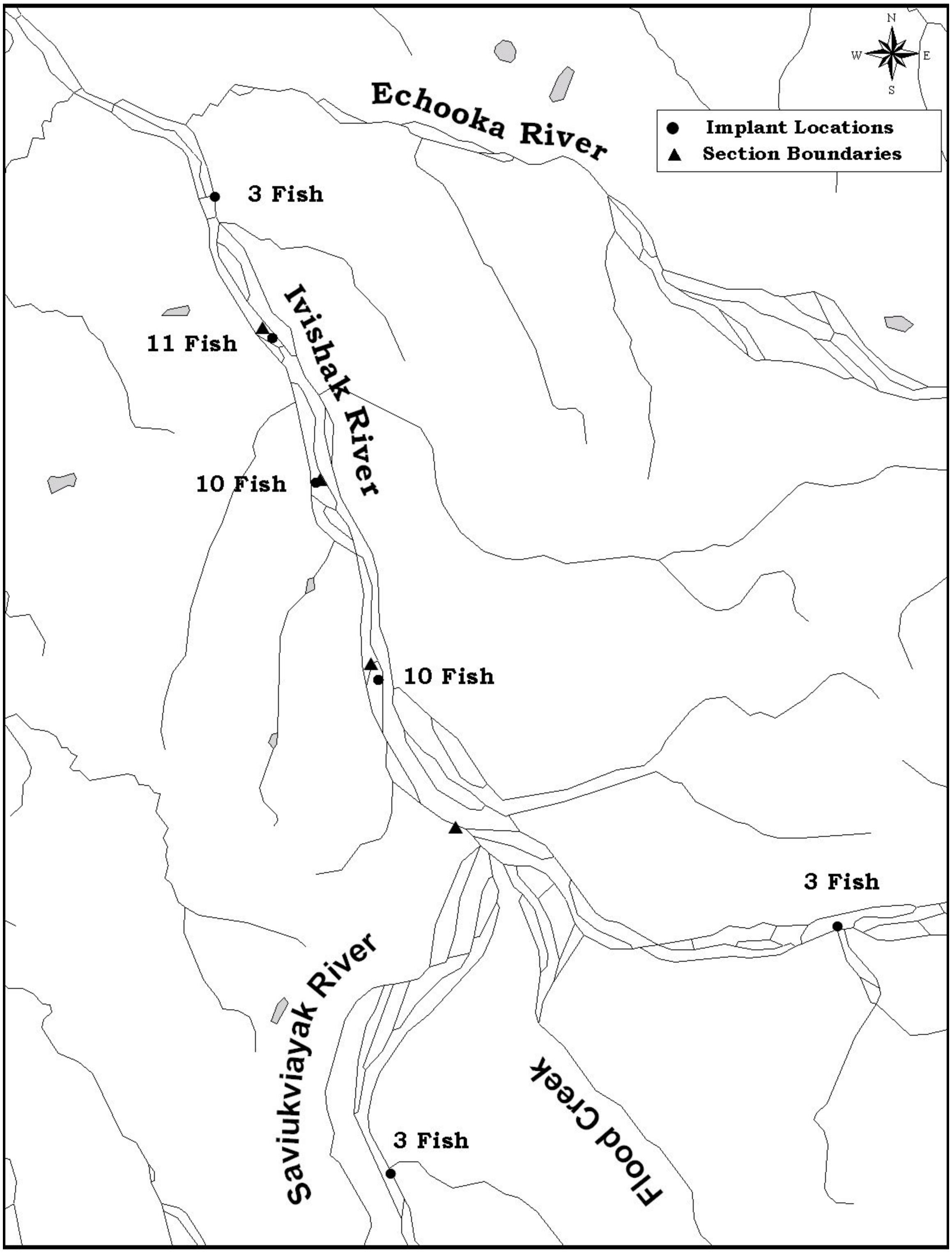

Figure 3.–Locations where radio-tagged Dolly Varden were captured and implanted in the Ivishak and Saviukviayak rivers, September, 2001.

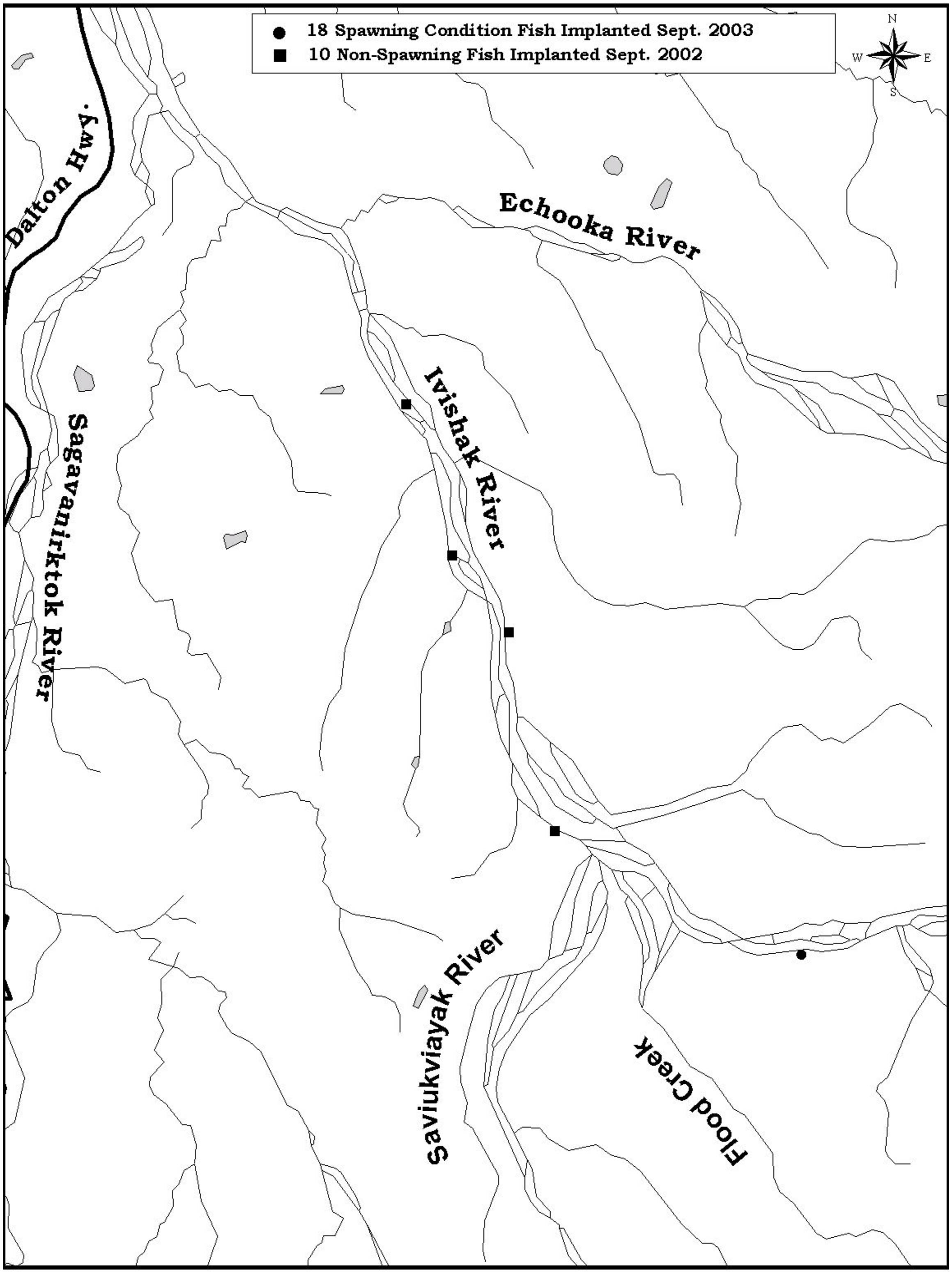

Figure 4.–Locations where radio-tagged Dolly Varden were captured and implanted in the Ivishak River, September, 2002, and September, 2003.

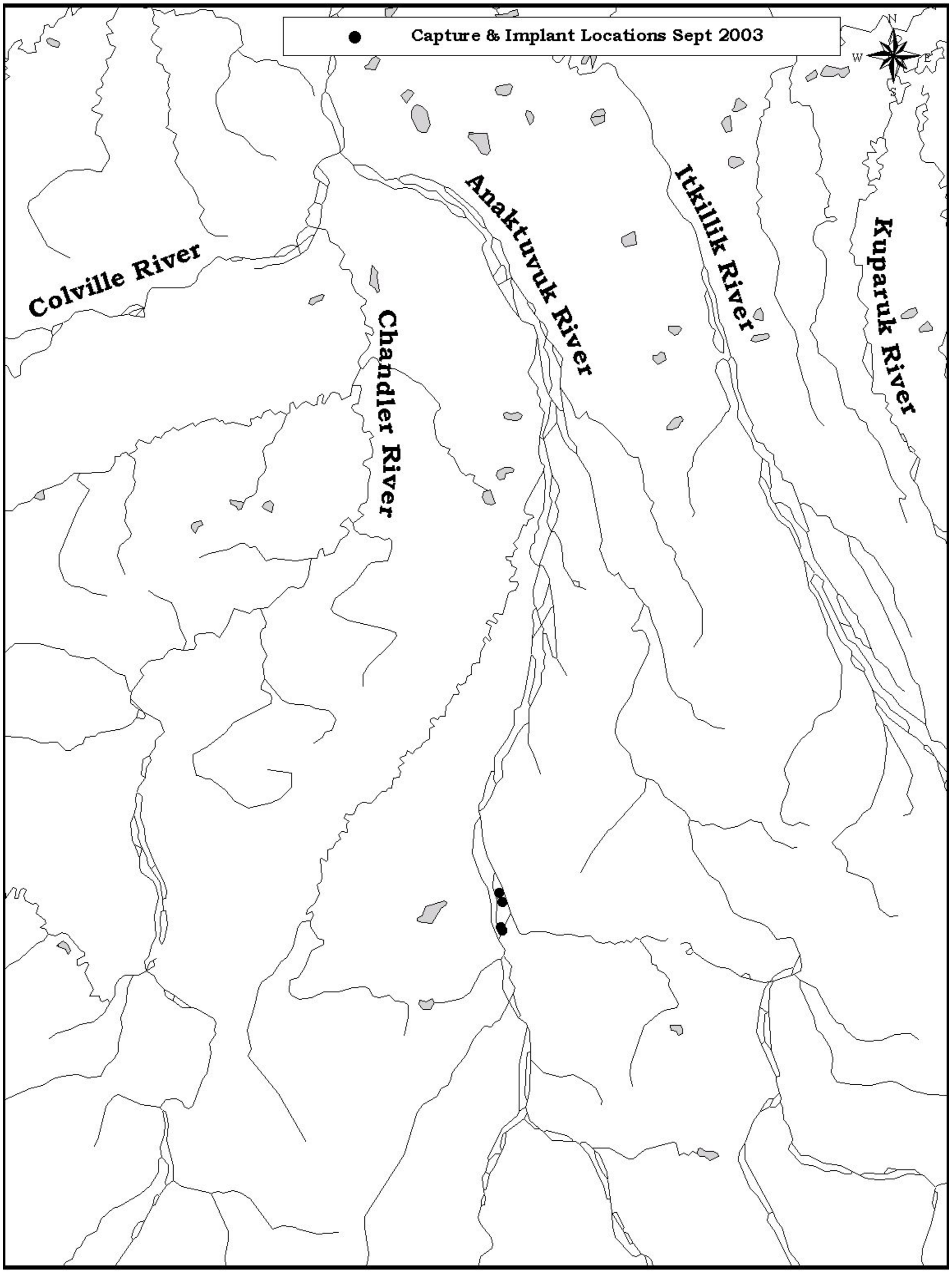

Figure 5.–Locations where radio-tagged Dolly Varden were captured and implanted in the Anaktuvuk River, September, 2003.

spawning Dolly Varden captured in the upper Ivishak River, about 10 km upstream of the index area (Figure 4) on September 20, 2003. Surveys were flown to locate these radio-tagged fish on September 22 and 24, 2003, to determine whether spawning fish had moved downstream into the index area during the mark-recapture experiment. Surveys of the Ivishak River were flown on September 22 and 24, 2003, to locate fish tagged in the Ivishak River during 2002. Finally, surveys were flown to locate radio-tagged Dolly Varden in the Anaktuvuk and Ivishak rivers on May 5, 2004, to identify overwintering sites.

SPAWNING LOCATIONS

Spawning locations were identified during aerial or ground surveys, and verified by on the ground examination of fish for spawning condition during August and September each year of the study. Over the three years of the study, spawning location surveys were conducted for the Ivishak, Echooka, Saviukviayak, Ribdon, Lupine, Kavik, Kongakut, and Anaktuvuk rivers. To confirm that these locations were Dolly Varden spawning sites, fish were captured with both hook-and-line and seines to determine their spawning condition. For all verified spawning locations, the GPS coordinates, approximate number of spawning fish observed, and date of the observation were recorded.

RESULTS

RADIOTELEMETRY DURING MARK-RECAPTURE ABUNDANCE ESTIMATION

Movement of Dolly Varden radio tagged within the 28 km index area during September of 2001 and 2002 was almost exclusively upstream. Fish tagged near the top of section 3 during 2002 remained within the index area, and did not move upstream. Pre-spawning fish tagged above the index area in 2003 did not move substantially during the mark-recapture experiment and none of them moved downstream towards or into the index area.

2001

All 34 non-spawning radio-tagged fish were located on September 17, 20, and 23. Most had moved upstream from their tagging location by September 17 (Figure 6). Several fish radio-tagged at the same location moved together, and were located very near each other on subsequent dates. Several locations on Figures 6-8 represent multiple fish. One fish tagged in section 2 moved downstream approximately 8 km into section 3 between September 17 and September 20 (Figure 7), but that same fish then moved approximately 12 km back upstream into section 2 by September 23 (Figure 8). All fish located except one (33 of 34) had moved upstream by September 23, and 30 of 34 were located in section 1 or the upper half of section 2. One of the three fish tagged below section 3 had moved into the upper half of section 1 by September 23.

2002

All Dolly Varden radio-tagged within and downstream of the index area (40) were located on September 19, 22, and 24, 2002. Most had moved upstream from the location they were tagged by September 19 (Figure 9). Although five of the 10 fish tagged near the top of section 1 had moved upstream by September 19th, only one moved upstream of the index area boundary, and this individual moved back downstream into the index area by September 22. Most (36 of 40) radio-tagged fish continued to move upstream by September 22 and 24 (Figures 10 and 11), but

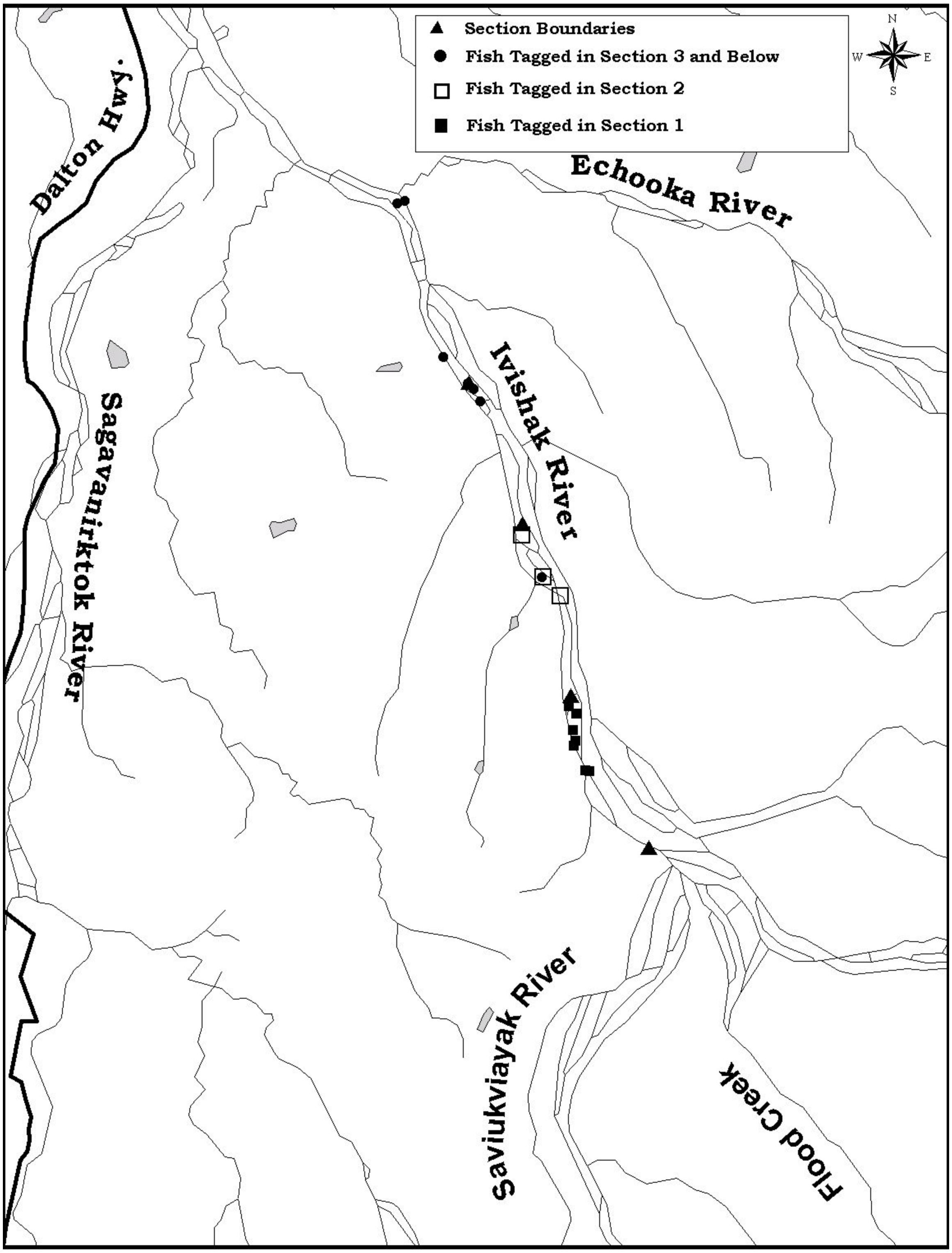

Figure 6.–Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 17, 2001.

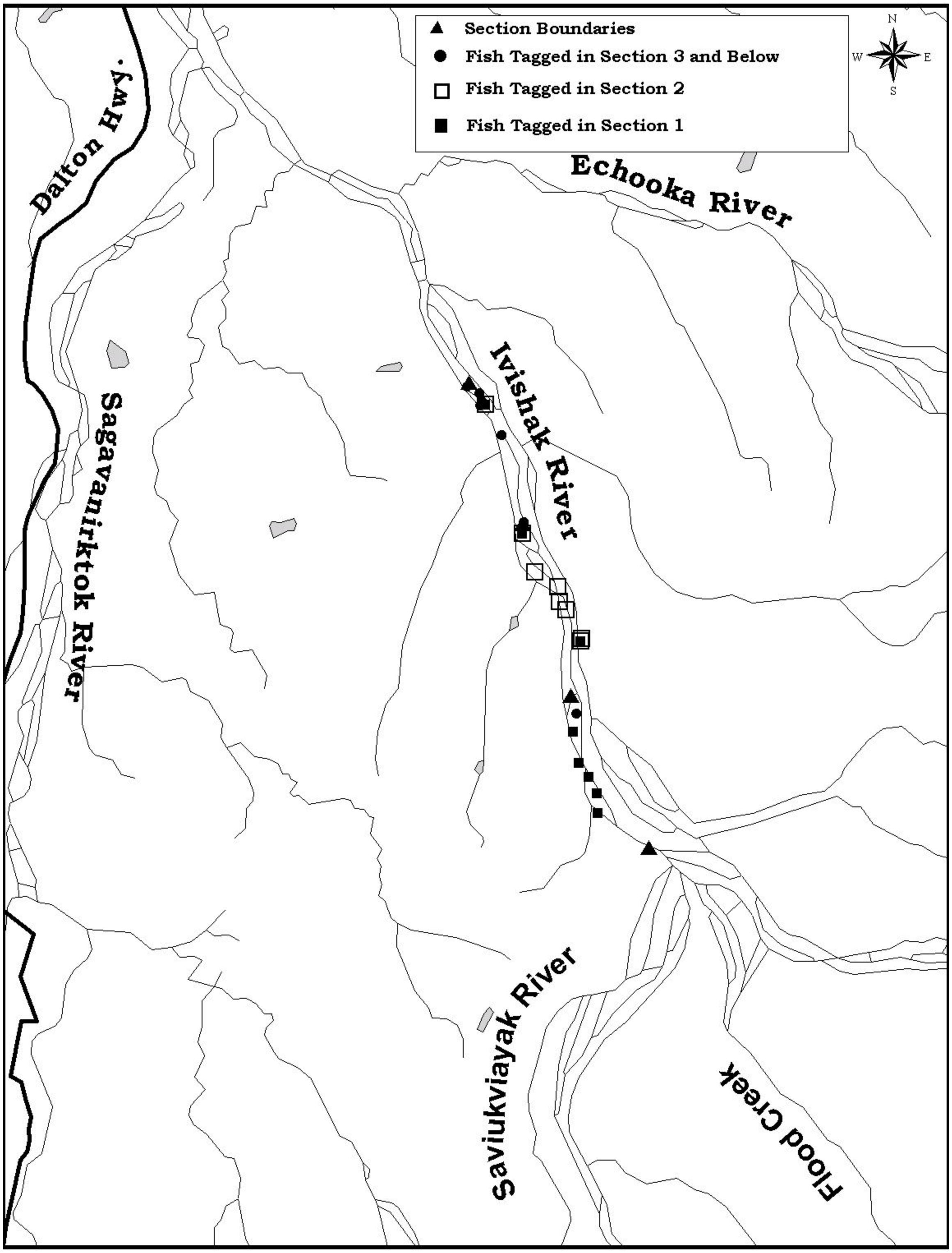

Figure 7.–Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 20, 2001.

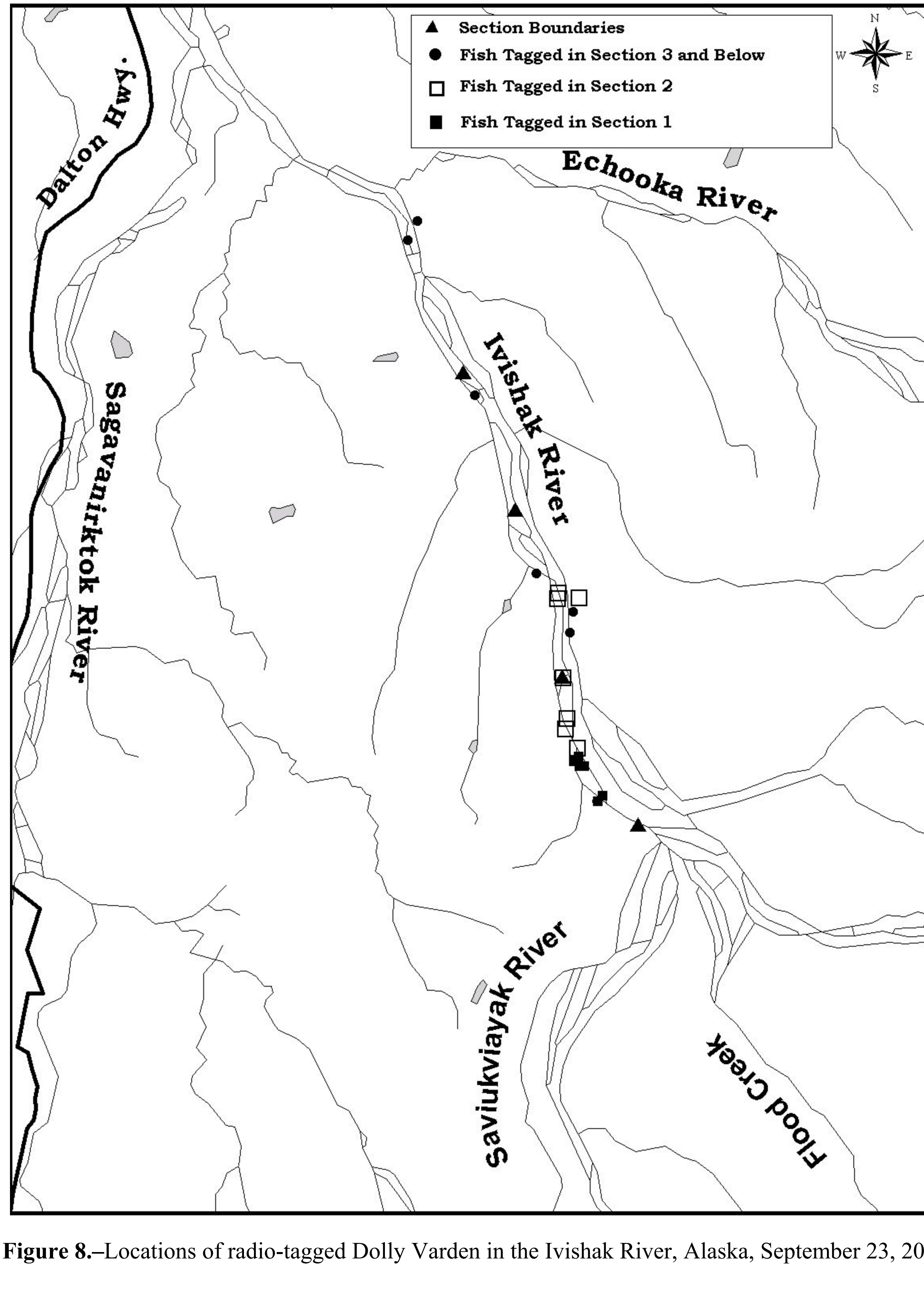

Figure 8.–Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 23, 2001.

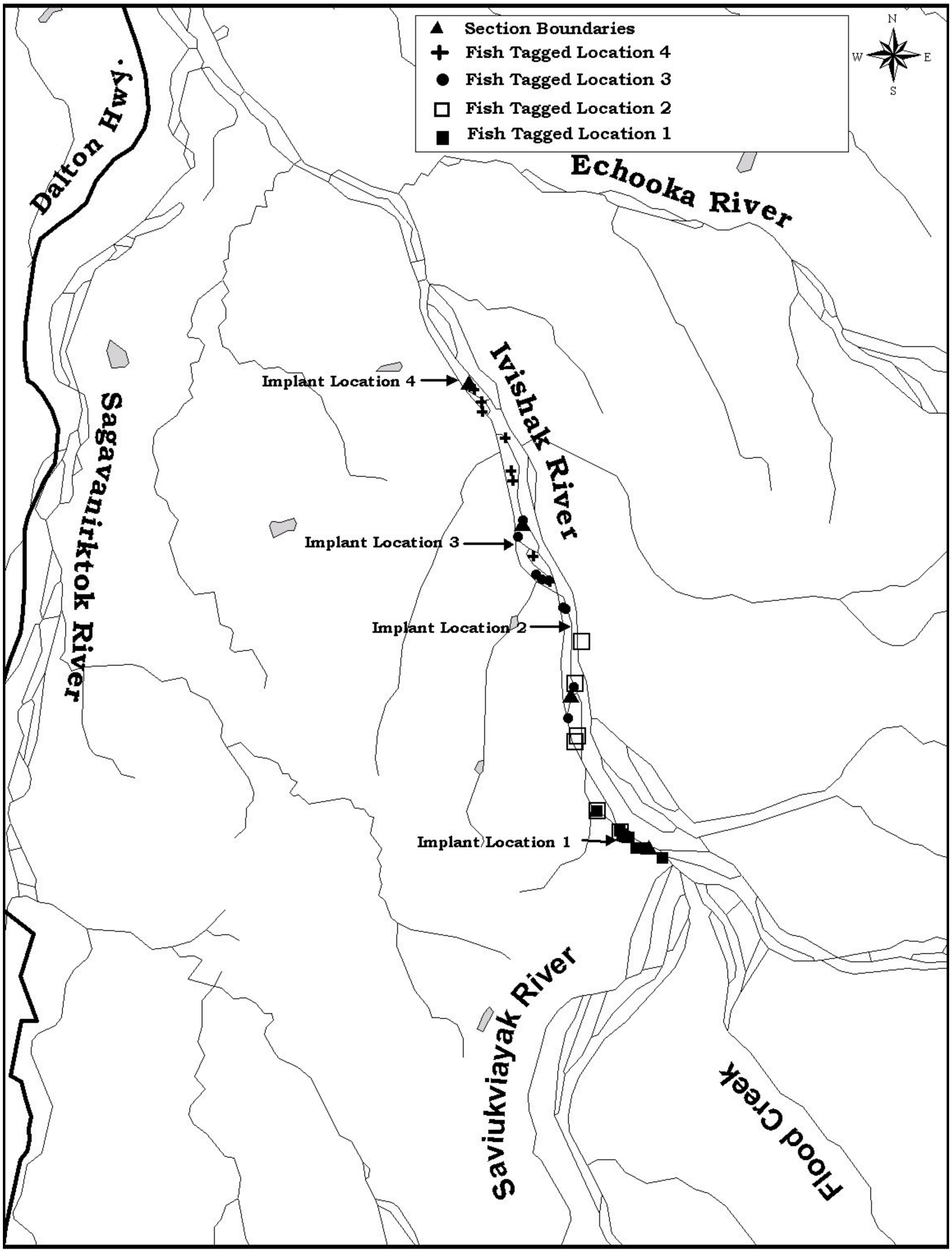

Figure 9.–Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 19, 2002.

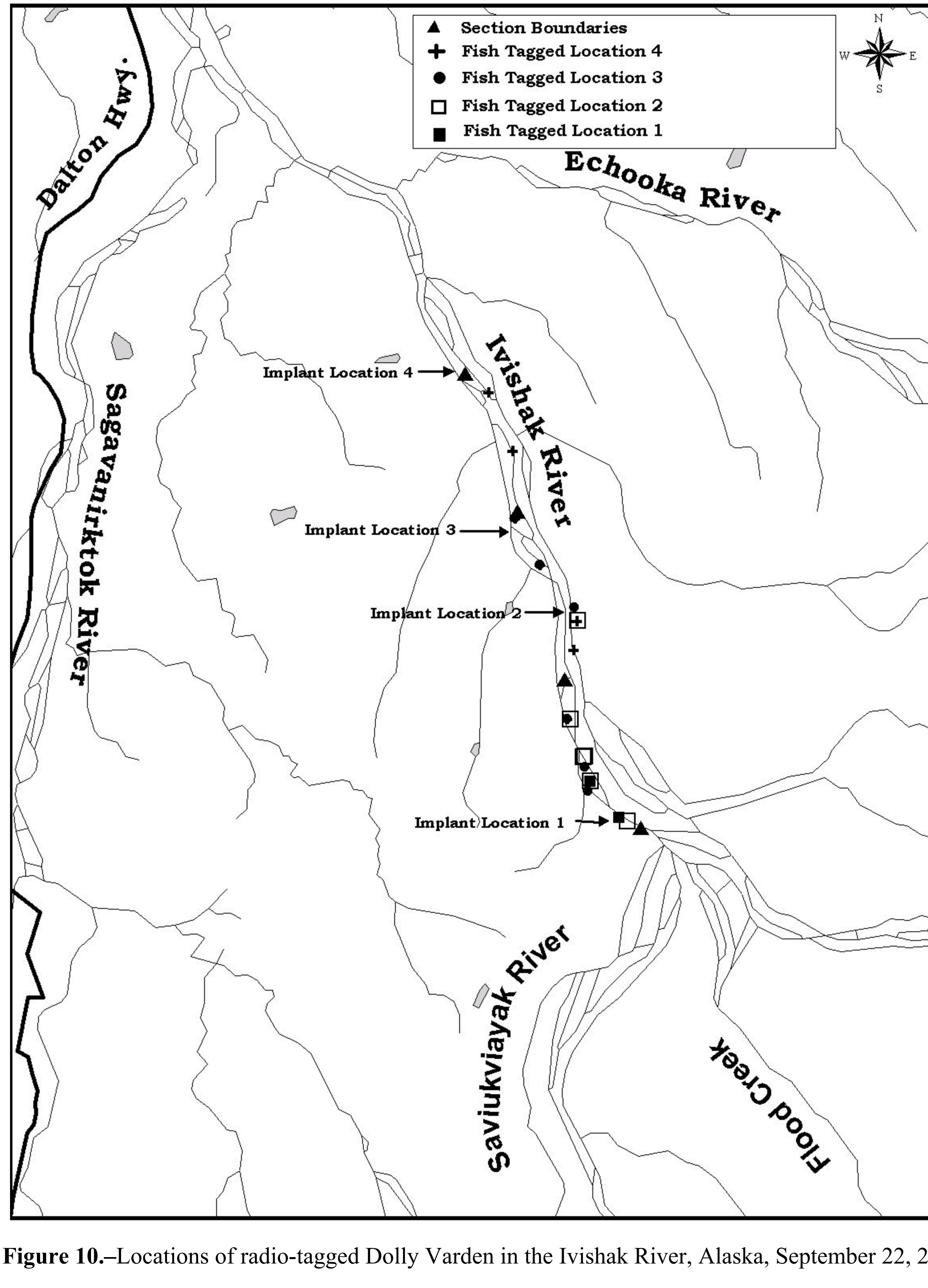

Figure 10.–Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 22, 2002.

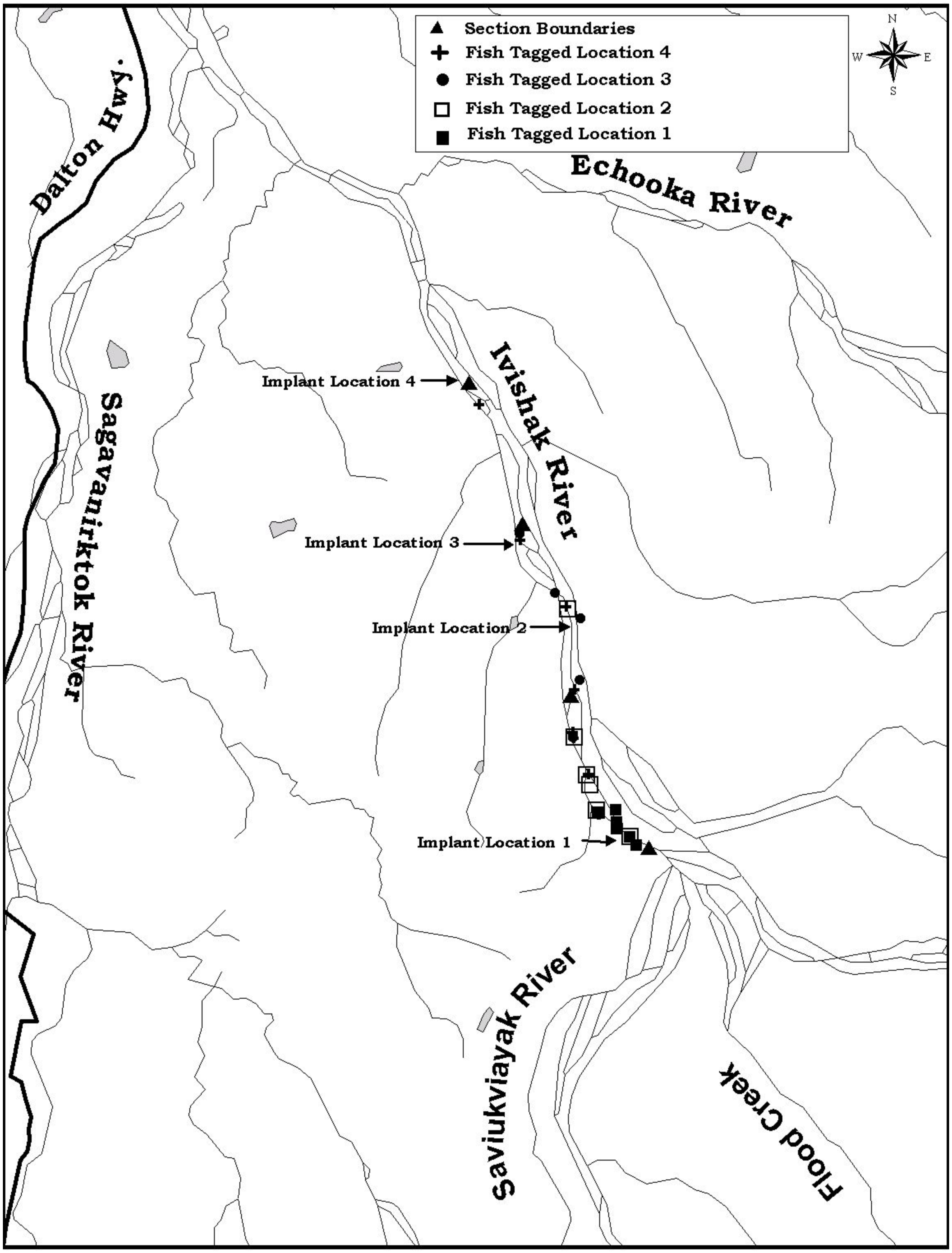

Figure 11.–Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 24, 2002

none moved out of the index area. The 10 fish tagged near the top of the index area all stayed relatively near the location they were tagged. Twelve pairs of fish that were radio-tagged at the same location moved together, and were located very near each other on subsequent dates.

No fish moved substantially downstream of their tagging location during the entire experiment, and no fish moved from the section in which they were tagged to a section downstream. One fish tagged at each of location stayed near their initial release location during the entire experiment. However, the location of each of these fish changed slightly during each radio tracking event, indicating that these fish were still alive. In addition to locating all 40 fish radio-tagged in September 2002, six fish radio-tagged in September 2001 were located during tracking flights in September 2002. Also, one non-spawning fish tagged in the Ivishak River in September 2001 was located with a group of spawning fish in the Kavik River in September 2002.

2003

All eighteen pre-spawning Dolly Varden radio-tagged in the Ivishak River during September 2003 were located on September 22 and 24, 2003 (Figures 12 and 13). These fish exhibited relatively little movement during that period, although they did disperse from the locations at which they were tagged (Figure 4). Most fish moved upstream, and none of them traveled downstream into the mark-recapture area. Additionally, 13 Dolly Varden radio-tagged in September 2002 were located. Eight of these fish were located upstream of the index area, including one located in Flood Creek, a tributary above the index area. Four of these Dolly Varden were located in the index area, and one was located below the index area, downstream of the Echooka River. Two additional radio-tags from releases in 2002 were located, but no movement was noted in response to the low-hovering helicopter. No fish were observed from the air at this location, so it was assumed these tags were either from individuals that died during the winter or that shed their tags. One of these tags was within the index area, and one just upstream of the upper boundary of the index area. All other radio-tagged fish that were located were judged to be alive because they moved during radio tracking or between location dates. One fish radio tagged in the Ivishak River during September, 2002, was returned by a subsistence user from Pt. Barrow who captured the fish in a gillnet in the Beaufort Sea near Cape Simpson, just east of Pt. Barrow, a distance of over 200 km west of the mouth of the Sagavanirktok River.

Mark-Recapture Abundance Estimation

Abundance estimates for the three years of the study showed a decreasing number of Dolly Varden returning to this overwintering location each year. The 2002 point estimate was approximately half of the 2001 estimate, and the 2003 estimate, although for a smaller section of river, was approximately half of the 2002 estimate. Relative precision of estimates was similar for all three years. The 2001 and 2002 estimates were both less precise than the objective, while the 2003 estimate more precise. A summary of all capture-recapture histories from each year's mark-recapture experiment appears in Appendix A.

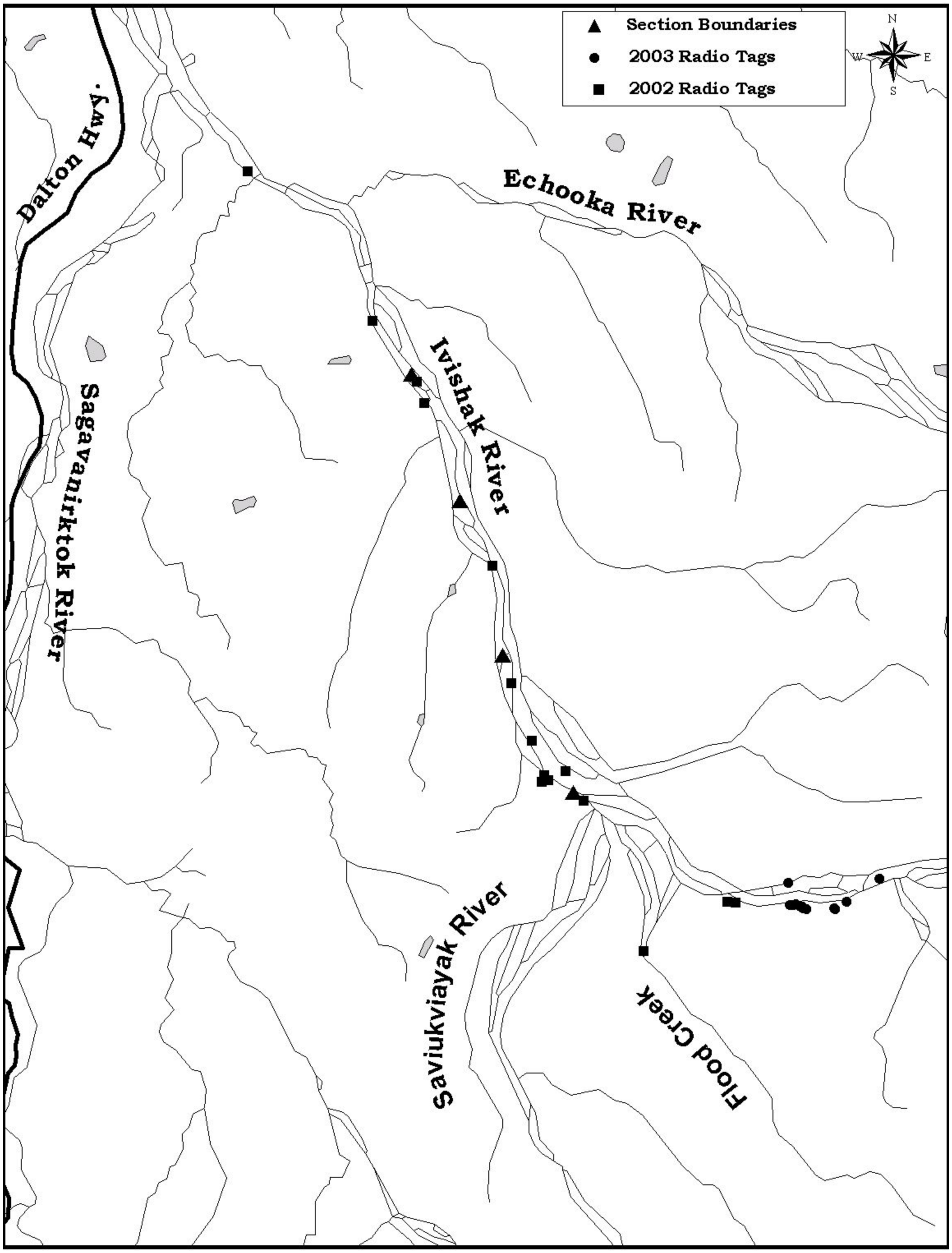

Figure 12.–Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 22, 2003.

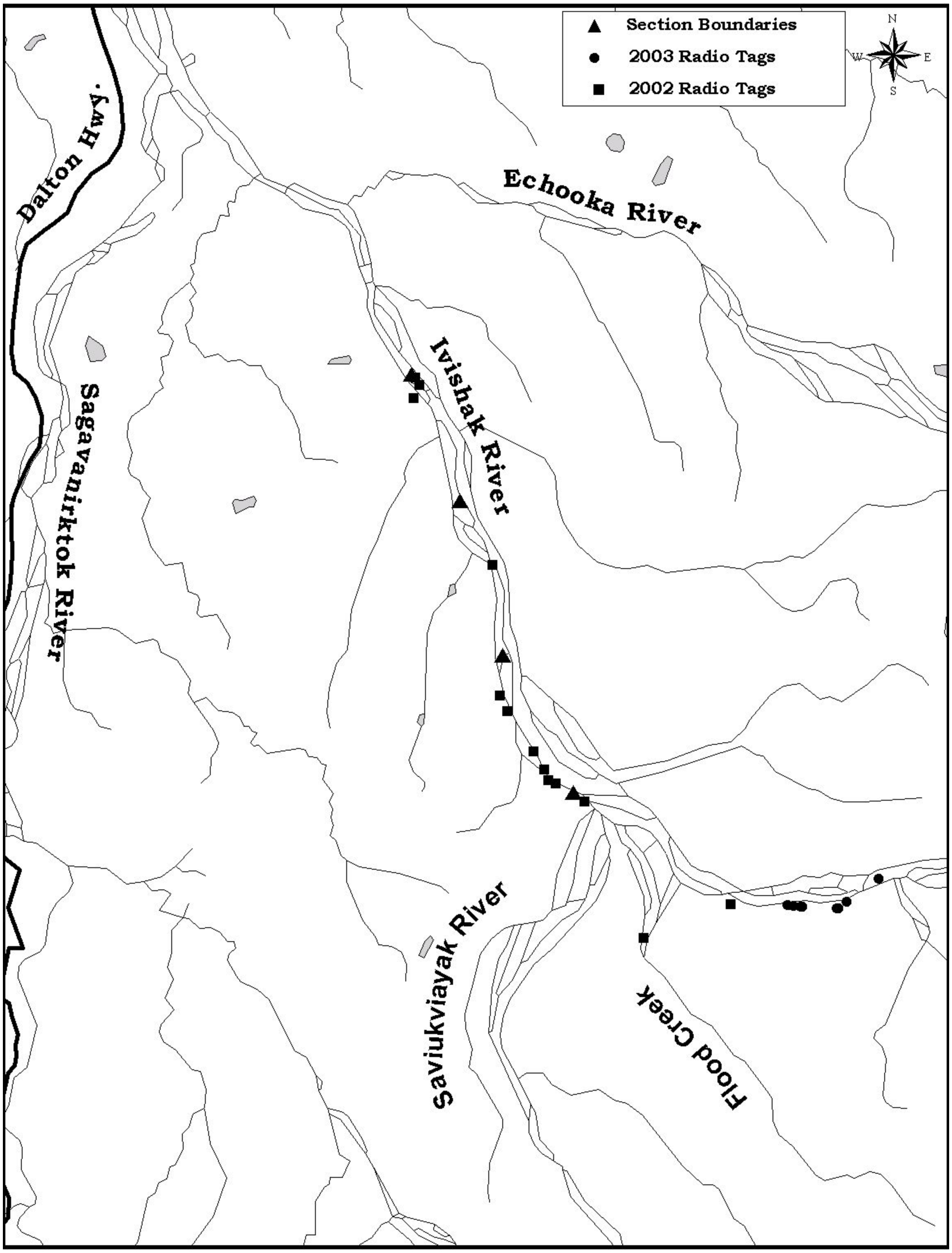

Figure 13.–Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 24, 2003.

2001

A total of 1,404 Dolly Varden were marked between September 14 and September 20, 2001. A total of 1,551 fish were examined during the first recapture event, between September 16 and 22, 2001. A second recapture event was conducted from September 21 to 23, and an additional 406 fish were examined. During the first recapture event, a total of 43 marked fish were recaptured. Information from the second recapture event only marginally improved the variance of the estimate, and only slightly altered the value of the estimate. For these reasons, and because sampling was not uniform throughout the study area in the second recapture event, samples from the second recapture event were not used in the abundance estimate analysis or for determining length composition.

There was no significant difference between size distributions of fish caught during the marking and first recapture event across the entire experimental area (K-S tests: MvR P=0.1191 and MvC P=0.4167).

The recapture data indicated that nearly half the fish present in Section 2 during the marking event had moved upstream into Section 1 by the time the recapture event was conducted, and a movement of similar magnitude occurred from Section 3 to Section 2. Observations of radio-tagged fish and distributions of fish during aerial surveys also indicated a large movement of fish from Section 2 to Section 1 and from Section 3 to Section 2 between the two sampling events. This information suggested there was mixing of marked and unmarked individuals within the study area.

Tests of consistency for the Petersen estimator indicated that an unstratified Bailey-modified Petersen estimator was the appropriate model to estimate abundance. The null hypotheses that movement between river sections was uniform and that recapture probabilities for fish marked in different river sections were uniform were both strongly rejected (P<0.0001 for both tests). However, the null hypothesis that the marked to unmarked fish ratios were uniform across sections of the river failed to be rejected (P=0.9051), indicating no evidence the probabilities of capture during the first event were not uniform across the study area. Estimated abundance was 49,523 Dolly Varden (SE=7,277).

2002

A total of 1,033 Dolly Varden were marked between September 14 and September 20, 2002. A total of 1,080 fish were examined during the first recapture event, between September 16 and 22, 2002. A second recapture event was conducted on September 23, and an additional 413 fish were examined. During the first recapture events, a total of 60 marked fish were recaptured. Information from the second recapture event only marginally improved the variance of the estimate, and only slightly altered the value of the estimate. Therefore, this information was not used for estimating either abundance or length composition.

Kolmogorov-Smirnoff tests were performed to evaluate the hypotheses of no difference between the size distributions of Dolly Varden marked during the first event (M), caught during the second event (C), and recaptured during the second event (R). When using data pooled from all three sections of the river the null hypotheses for both K-S tests were rejected (MvR P=0.0006 and MvC P<0.0001), indicating that the estimator used would have to be stratified by size at 360 mm FL.

Observations of radio-tagged fish and aerial surveys during the mark/recapture experiment both indicated a large upstream movement of fish from Section 2 to Section 1 and from Section 3 to Section 2 between the two sampling events. This suggested mixing of marked and unmarked fish within the study area. However, recaptures of marked fish occurred almost entirely within the same section in which fish were marked (Appendix A).

When the tests for consistency for the Petersen estimator were evaluated, it was concluded that the Bailey-modified Petersen estimator was appropriate for estimating abundance for the large size stratum, and a fully geographically stratified Bailey-modified Petersen estimator was appropriate for the small size stratum. For both size strata the null hypothesis that mixing between river sections was complete was rejected ($P<0.001$). For the large size stratum, capture probabilities for the first and second events were uniform across sections of the river ($P=0.99$ and $P=0.70$). For the small size stratum, however, capture probabilities for the events were not uniform across sections of the river ($P=0.04$ and $P=0.001$) and no marked fish were observed to have moved between sections. Estimated abundance for all fish (estimates from both strata combined) was 21,634 Dolly Varden (SE=3,075).

2003

A total of 855 Dolly Varden were marked between September 14 and September 20, 2003. Unfortunately, river icing made boat travel and seining impossible near the end of the experiment, so a recapture event could not be conducted in Section 3. Because of this, the mark-recapture population estimate was limited to Sections 1 and 2 only. A total of 749 fish were marked in Sections 1 and 2, and a total of 716 fish were captured and examined during the recapture event. During the recapture event, 57 marked fish were recaptured.

Kolmogorov-Smirnoff tests were performed to test the hypotheses of no difference between size distributions of Dolly Varden marked during the first event (M) with those examined during the second event (C) and marked fish recaptured during the second event (R). When using data pooled from sections 1 and 2 of the river, the null hypotheses was rejected for the MvC test ($P=0.032$), but the null hypothesis failed to be rejected for the MvR test ($P=0.135$). This implied there was size selectivity during the first event, but not during the second event, so the estimate would not have to be stratified by size (Table 2).

When the tests of consistency for the Petersen estimator were evaluated, results indicated that the Bailey-modified Petersen estimator was the appropriate model. Most Dolly Varden were recaptured in the same section in which they were marked, and aerial surveys during the mark-recapture experiment suggested there was incomplete mixing between the two events. However, the null hypotheses that capture probabilities were uniform across sections during both events were not rejected ($P = 0.474$ for the first event and $P = 0.474$ for the second event). Estimated abundance of Dolly Varden > 220 mm was 9,259 fish (SE = 1,156) in sections 1 and 2 of the study area.

LENGTH COMPOSITION IN MARK-RECAPTURE ASSESSMENT

During a feasibility study in September of 2000 (Viavant 2001), a total of 1,122 Dolly Varden were captured, marked, and measured. The mean length of fish captured was 452 mm fork length (FL). The smallest fish captured was 335 mm FL and the largest was 710 mm FL. Most fish captured were between 360 and 500 mm FL, and the distribution of lengths was unimodal. The peak of the distribution was about 400 mm FL (Figure 14).

During 2001, KS tests on capture data did not indicate sampling was size-selective during either event (Case I from Table 2), so all 2,955 fish captured were used to estimate length composition. Mean length of all fish captured was 447 mm FL. The smallest fish captured was 225 mm FL and the largest was 710 mm FL. Most fish captured were between 350 and 560 mm FL, and the distribution of lengths was unimodal. The peak of the distribution was about 425 mm FL (Figure 14).

During 2002, the abundance estimate was stratified by length at 360 mm. For fish ≥ 360 mm FL (the large size strata), K-S tests on capture data indicated sampling was size-selective during the first event (Case II; Table 2), so only fish from the second sampling event were used to estimate length composition for the large size strata. For fish < 360 mm FL (the small size strata), K-S tests indicated sampling was not size–selective in any geographic strata (Case I; Table 2), so fish from both events were used to estimate length composition. The mean length of all fish captured was 450 mm FL. The smallest fish captured was 220 mm FL and the largest was 715 mm FL. The length distribution of fish captured during 2002 was bimodal, with a small peak around 260 mm FL and a larger peak around 485 mm FL (Figure 14).

During 2003, length data were not stratified, but K-S tests indicated that sampling was size-selective during the first event (Case II, Table 2), so only fish from the second sampling event were used to estimate length composition. The mean length of all fish captured was 433 mm FL. The smallest fish captured was 220 mm FL and the largest was 675 mm FL. The length distribution of fish captured during 2003 was distinctly bimodal, with a large peak around 330 mm FL and a smaller peak around 540 mm FL (Figure 14). There were relatively few fish captured were between 400 and 460 mm FL.

AERIAL SURVEY VARIABILITY ESTIMATION

Replicate aerial survey counts of the 28-km index area of the Ivishak River were internally precise within each year, with standard errors of mean summed counts ranging between 2.9% and 6.7% of the mean summed count of that year's surveys (Table 4). The mean summed count for the entire index area fell by approximately half between each of the three years of the study. The average mean summed count for each year represented between 22% and 25% of the mark-recapture estimate for each year. Because the mark-recapture estimate for 2003 was only for sections 1 and 2 of the index area, it was compared to the aerial count for sections 1 and 2.

Table 4.–Paired average Dolly Varden aerial survey counts and mark-recapture abundance estimates from a 28 km index area of the Ivishak River, Alaska, 2001-2003.

Study Year	Mean Summed Aerial Count	Aerial Count Standard Error	Mark-Recapture Estimate	Mark Recapture Standard Error	Aerial Count as percentage of Mark-Recapture Estimate
2001	10,932	314	49,523	7,277	0.221
2002	5,408	363	21,634	3,075	0.250
2003	2,187[a]	131	9,259[a]	1,156	0.236

[a] Mean summed aerial count and mark-recapture estimate for 2003 are for Sections 1 and 2 only.

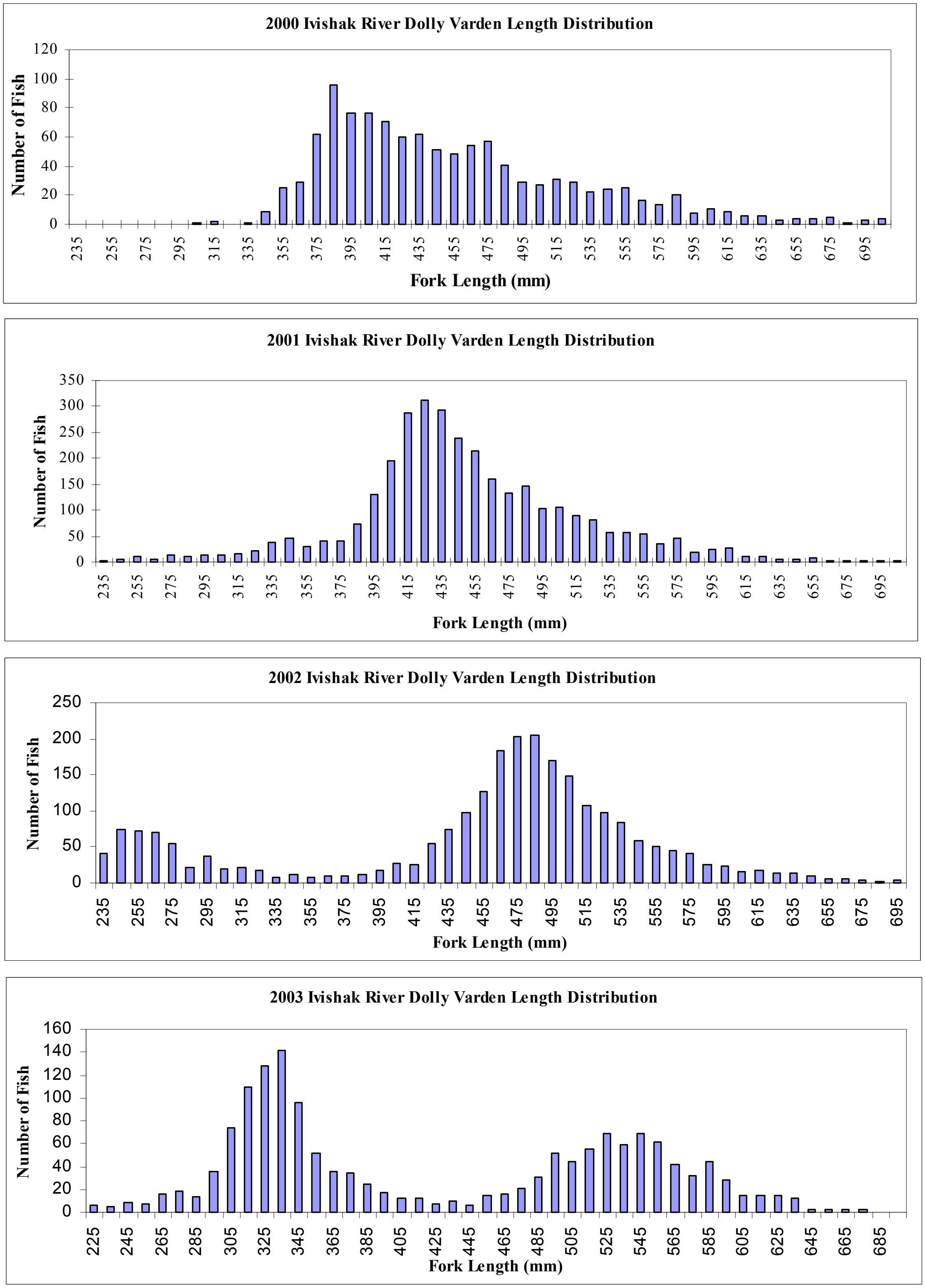

Figure 14.–Length distribution of overwintering Dolly Varden captured in the Ivishak River, September 2000 (n = 1,122), September, 2001 (n = 2,955), September 2002 (n = 1,253), and September 2003 (n = 716).

Net movement of fish was upriver during the time surveys were flown. Counts were generally higher upriver than downriver, and counts also tended to increase upriver and decrease downriver over the period that surveys were conducted (Table 5). In general, the variability of counts was greater in lower river sections, where fish were less abundant. Observer two tended to count more fish than observer one, and average counts (all sections over all replicates within a year) made by observer two were less variable than those made by observer one.

Overwintering Locations

Overwintering locations of Dolly Varden in the Ivishak River were determined by locating radio-tagged fish during April 2002. Thirty-eight overwintering fish of the 40 that were tagged during September 2001 were located during April 2002. In April 2002, fish were dispersed within, upstream, and downstream of the 28 km index area (Figure 15). Almost half (18 of 38) of the fish had moved downstream from their September 2001 locations.

During April 2003, all 40 fish radio-tagged in September 2002 were located, as well as six fish radio-tagged in 2001 that had returned to the index area in fall 2002. During April 2003, overwintering fish were dispersed within and downstream of the 28 km index area, but no fish were found upstream of the index area (Figure 16).

On May 4, 2004, all 18 spawning-condition fish tagged in the upper Ivishak River tagged in September 2002 as well as 12 of 13 non-spawning fish tagged in September 2002 that had returned to the Ivishak River in September, 2003 were located. These fish were distributed widely, primarily within the index area, with a few fish both upstream and downstream of the index area boundaries (Figure 17). Also on May 4, 2004, 22 of the 23 non-spawning fish tagged in the Anaktuvuk River in September 2003 were located, all within a relatively short distance from their tagging location (Figure 18). During summer 2004, two of these fish were captured approximately 75 km upstream from their overwintering location by subsistence users from Anaktuvuk Pass.

Spawning Locations

Spawning locations were identified or verified on the Kongakut River during the feasibility study in 2000 (Figure 19), the Ivishak, Echooka, and Saviukviayak rivers during 2001, 2002, and 2003 (Figure 20), and the Anaktuvuk, Kanayut, Kavik, Ribdon, Lupine, and Shaviovik rivers during 2002 (Figures 20 and 21). Spawning locations identified in most systems were near the upper reaches of the drainages in the Brooks Range or its foothills. Many of these spawning areas were associated with obvious spring activity or were in channels along vertical rock bluffs. GPS coordinates for all locations and approximate numbers of fish at each location were documented (Appendix B).

Table 5.–Aerial counts of Dolly Varden in a 28 km index reach of the Ivishak River, September 2001, 2002, and 2003.

Replicate Date	Survey Conditions	Section	Observer	Section Count	Section Total	Replicate Total
9/19/2001	Excellent	1	1	2,400	6,250	10,450
			2	3,850		
		2	1	920	3,340	
			2	2,420		
		3	1	210	860	
			2	650		
9/20/2001	Excellent	1	1	2,840	7,650	12,085
			2	4,810		
		2	1	1,390	3,215	
			2	1,825		
		3	1	520	1,220	
			2	700		
9/21/2001	Good	1	1	3,960	7,765	10,415
			2	3,805		
		2	1	910	2,110	
			2	1,200		
		3	1	240	540	
			2	300		
9/22/2001	Good	1	1	3,130	7,865	10,595
			2	4,735		
		2	1	1,245	1,985	
			2	740		
		3	1	470	745	
			2	275		
9/23/2001	Good	1	1	4,570	8,920	11,115
			2	4,350		
		2	1	1,030	1,335	
			2	305		
		3	1	660	860	
			2	200		

Summary Statistics by Section and Observer

	Section 1	Section 2	Section 3	Summed Counts
Mean Count	7,690	2,397	845	10,932
Standard Error	425	383	110	314
Standard Error as Percent of Mean[a]	5.5	16	13.1	2.8

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Table 5.–Page 2 of 3.

Replicate Date	Survey Conditions	Section	Observer	Section Count	Section Total	Replicate Total
9/18/2002	Good	1	1	1,530	3,366	5,503
			2	1,836		
		2	1	255	1,390	
			2	1,135		
		3	1	117	747	
			2	630		
9/19/2002	Good	1	1	1,110	2,620	5,302
			2	1,510		
		2	1	222	1,442	
			2	1,220		
		3	1	260	1,240	
			2	980		
9/20/2002	Good	1	1	1,761	2,969	4,190
			2	1,208		
		2	1	205	721	
			2	516		
		3	1	164	500	
			2	336		
9/21/2002	Excellent	1	1	3,130	5,060	6,455
			2	1,930		
		2	1	190	980	
			2	790		
		3	1	195	415	
			2	220		
9/22/2002	Excellent	1	1	2,825	4,455	5,588
			2	1,630		
		2	1	260	790	
			2	530		
		3	1	228	343	
			2	115		

Summary Statistics by Section and Observer

	Section 1	Section 2	Section 3	Summed Counts
Mean Count	3,694	983	694	5,408
Standard Error	1,028	150	163	363
Standard Error as Percent of Mean[a]	12.4	15.2	25	6.7

-continued-

Table 5.–Page 3 of 3.

Replicate Date	Survey Conditions	Section	Observer	Section Count	Section Total	Replicate Total
9/17/2003	Excellent	1	1	369	1,277	2,252
			2	858		
		2	1	217	509	
			2	292		
		3	1	427	516	
			2	89		
9/20/2003	Good	1	1	836	1,833	2,893
			2	997		
		2	1	243	496	
			2	253		
		3	1	245	564	
			2	319		
9/21/2003	Excellent	1	1	813	1,904	2,848
			2	1,091		
		2	1	104	261	
			2	157		
		3	1	300	683	
			2	383		
9/22/2003	Excellent	1	1	571	1,669	2,610
			2	1,098		
		2	1	162	504	
			2	342		
		3	1	278	437	
			2	159		
9/23/2003	Excellent	1	1	328	2,187	2,998
			2	1,859		
		2	1	74	346	
			2	272		
		3	1	113	465	
			2	352		

	Section 1	Section 2	Section 3	Summed Counts
Mean Count	1,764	423	533	2,720
Standard Error	158	51	43	133
Standard Error as Percent of Mean[a]	9%	12%	8%	5%

[a] Coefficient of variation (CV).

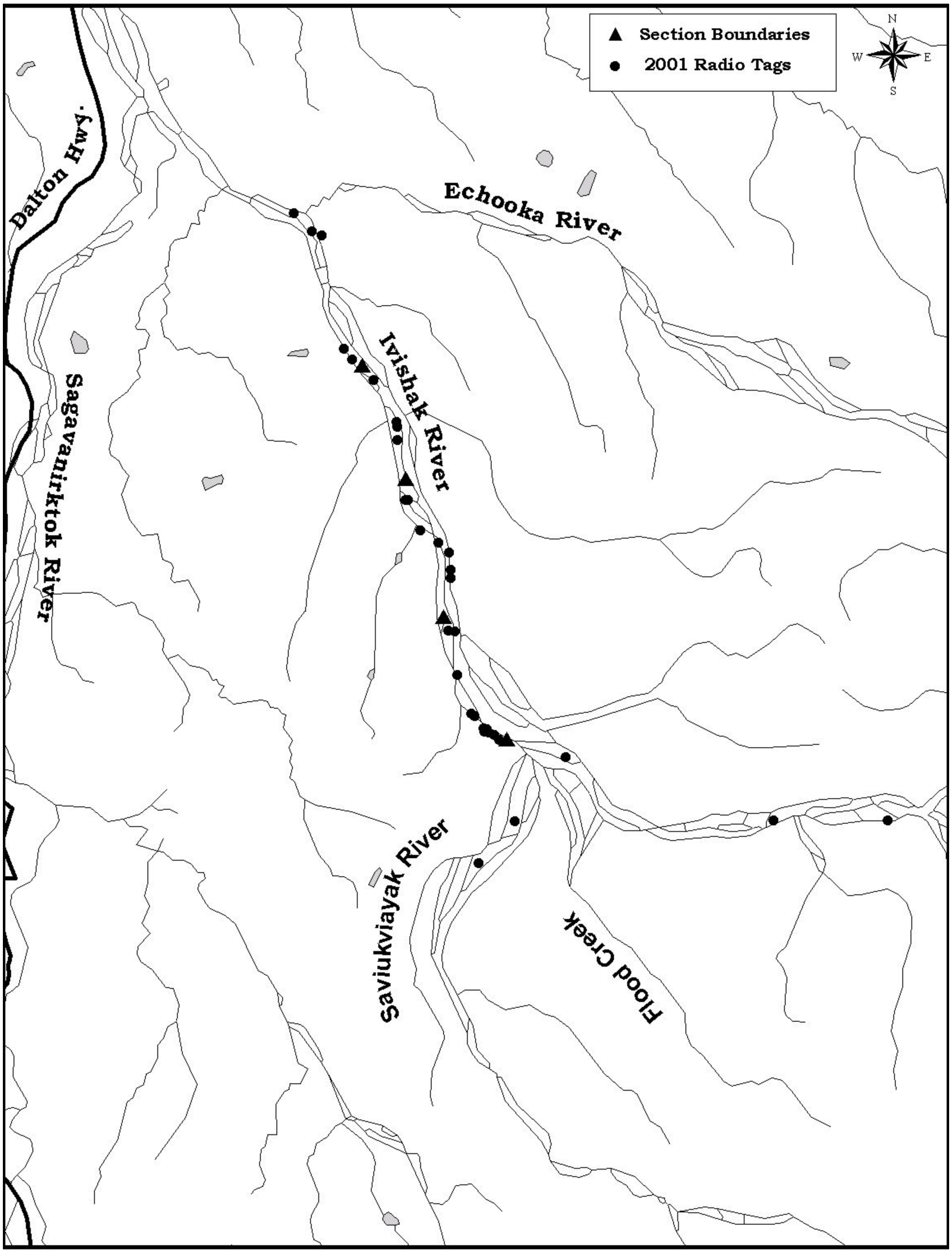

Figure 15.–Dolly Varden overwintering locations in the Ivishak River, April 2002**.**

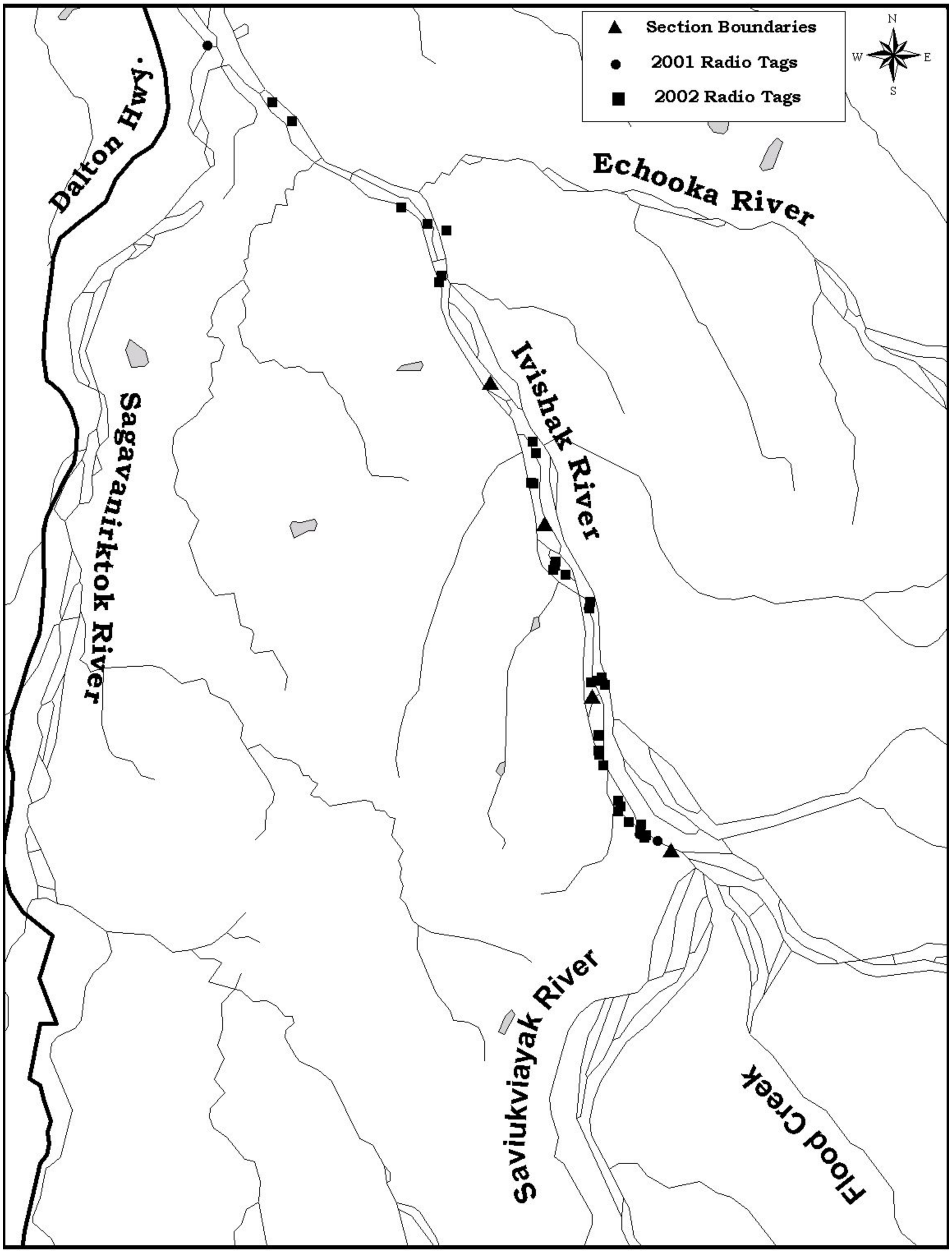

Figure 16.–Dolly Varden overwintering locations in the Ivishak River, April 2003.

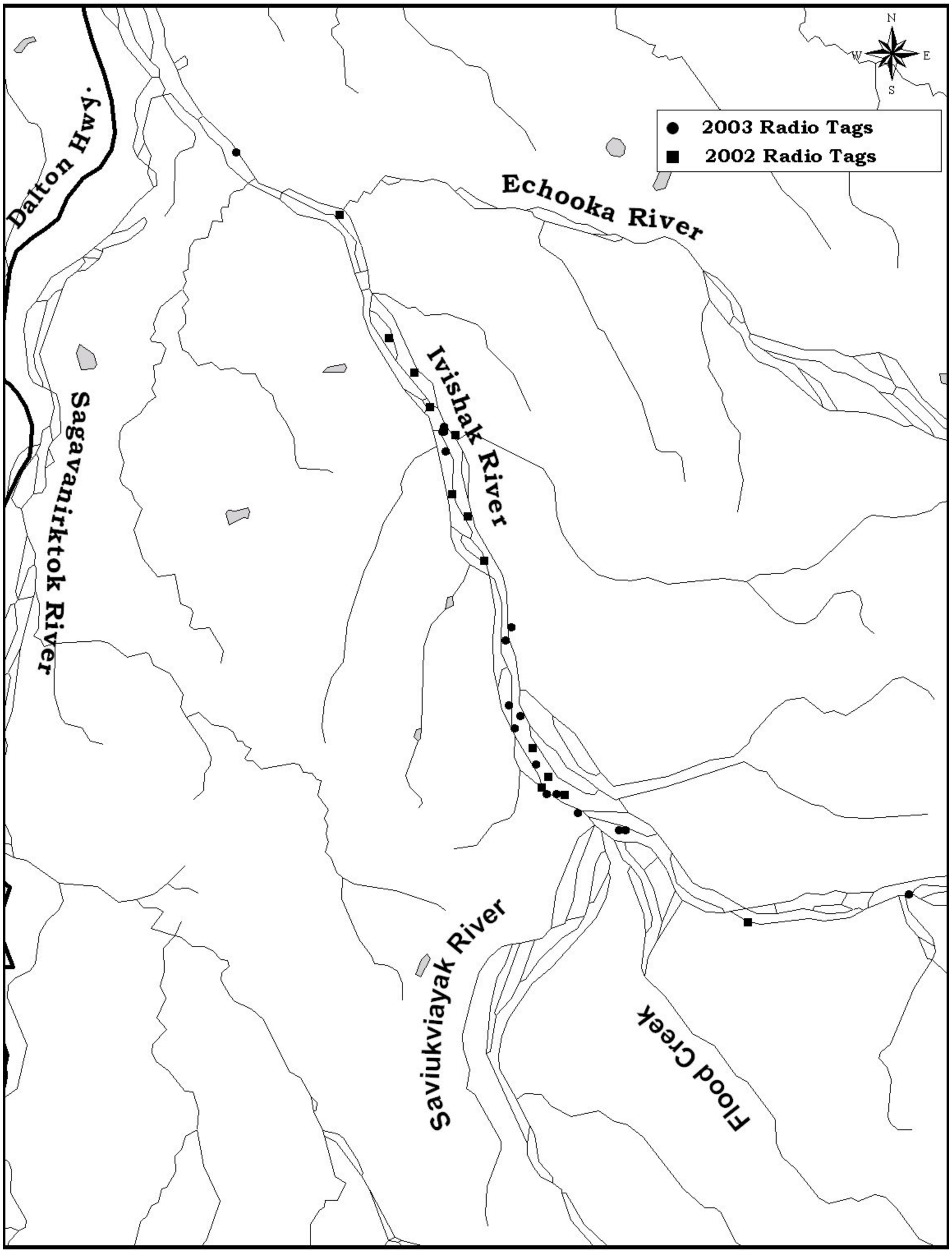

Figure 17.–Dolly Varden overwintering locations in the Ivishak River, May 2004.

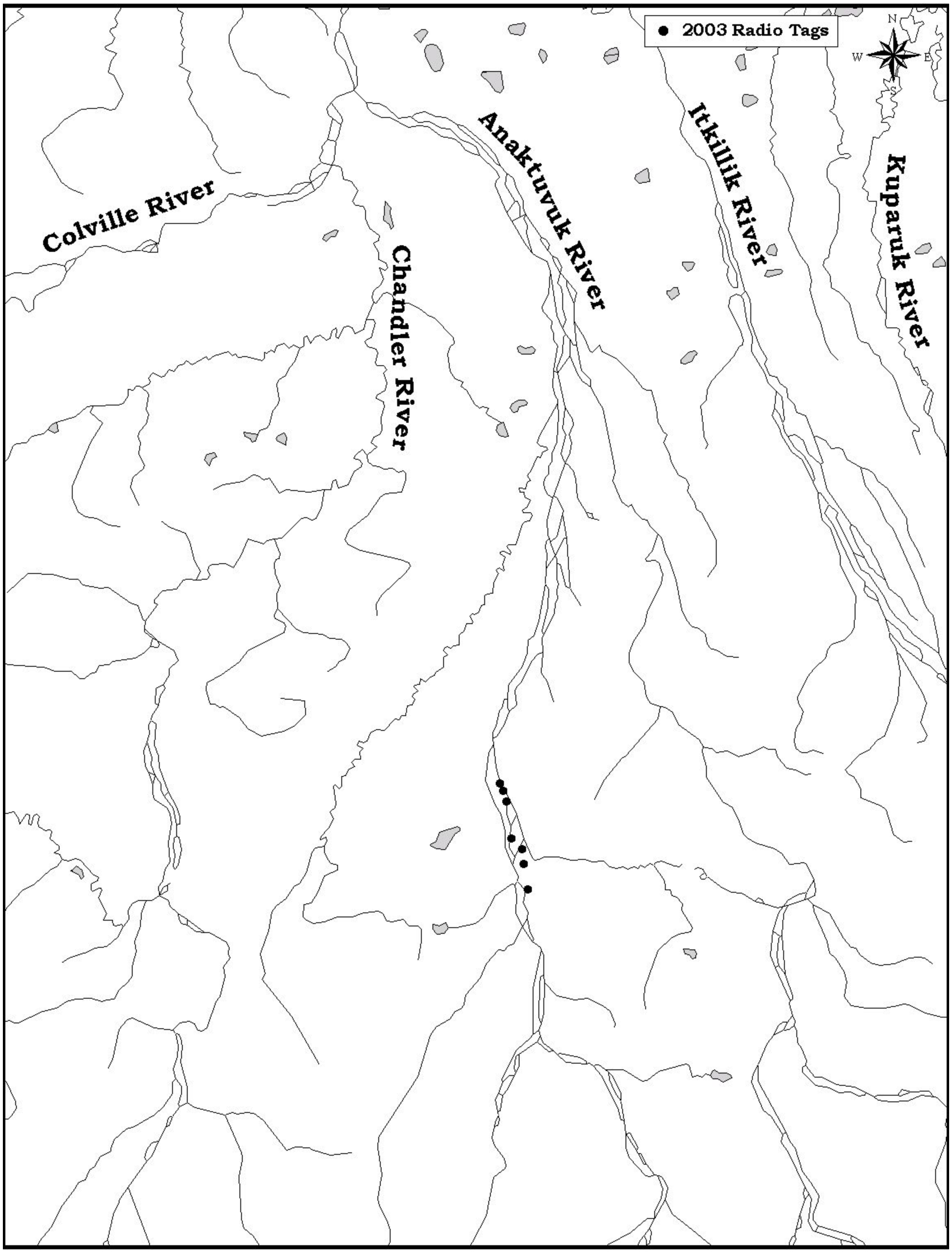

Figure 18.–Dolly Varden overwintering locations in the Anaktuvuk River, May 2004.

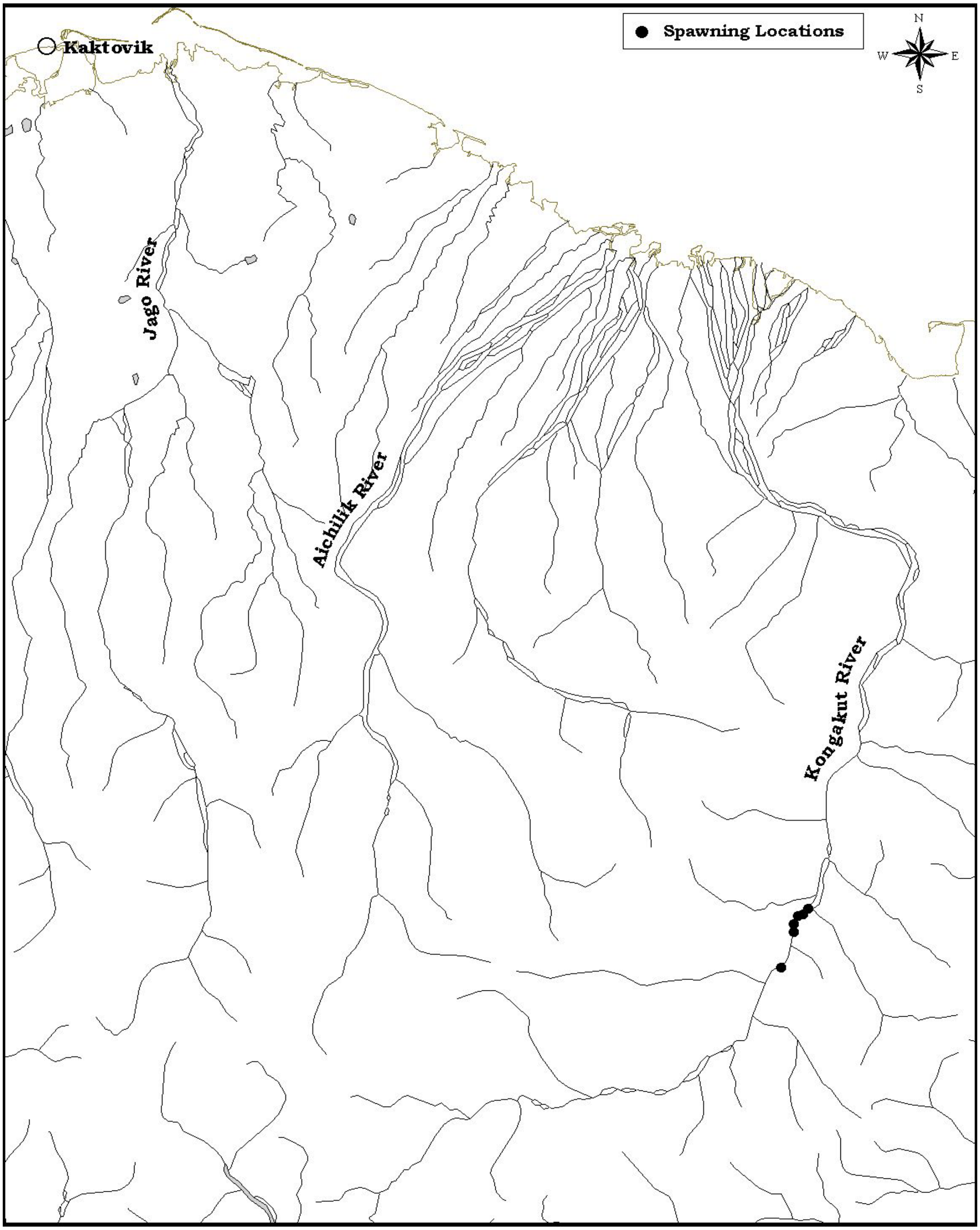

Figure 19.–Dolly Varden spawning locations in the Kongakut River, August 2000.

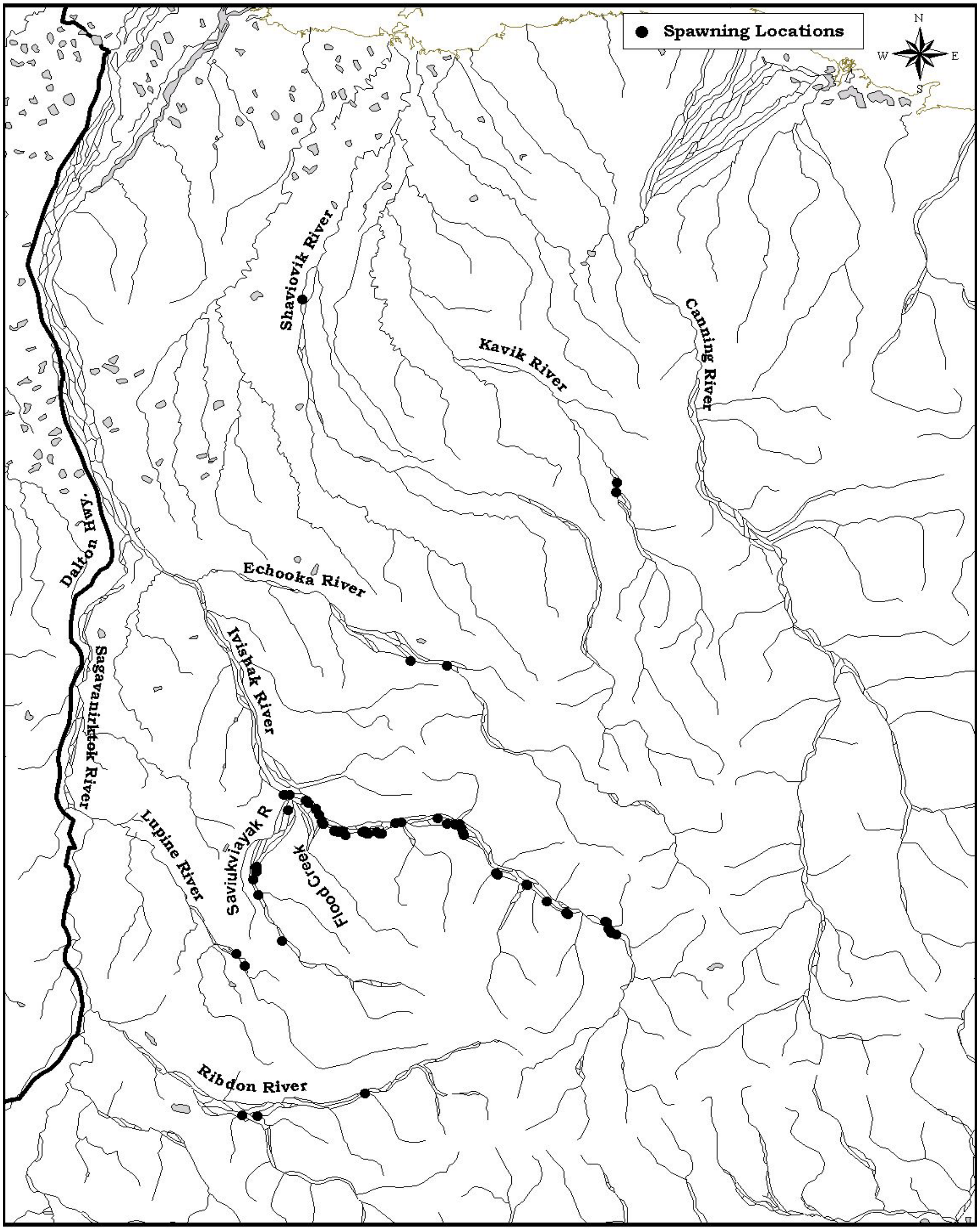

Figure 20.–Dolly Varden spawning locations in the Ribdon, Lupine, Saviukviayak, Ivishak, Echooka, Shaviovik, and Kavik rivers, September 2001, 2002, and 2003.

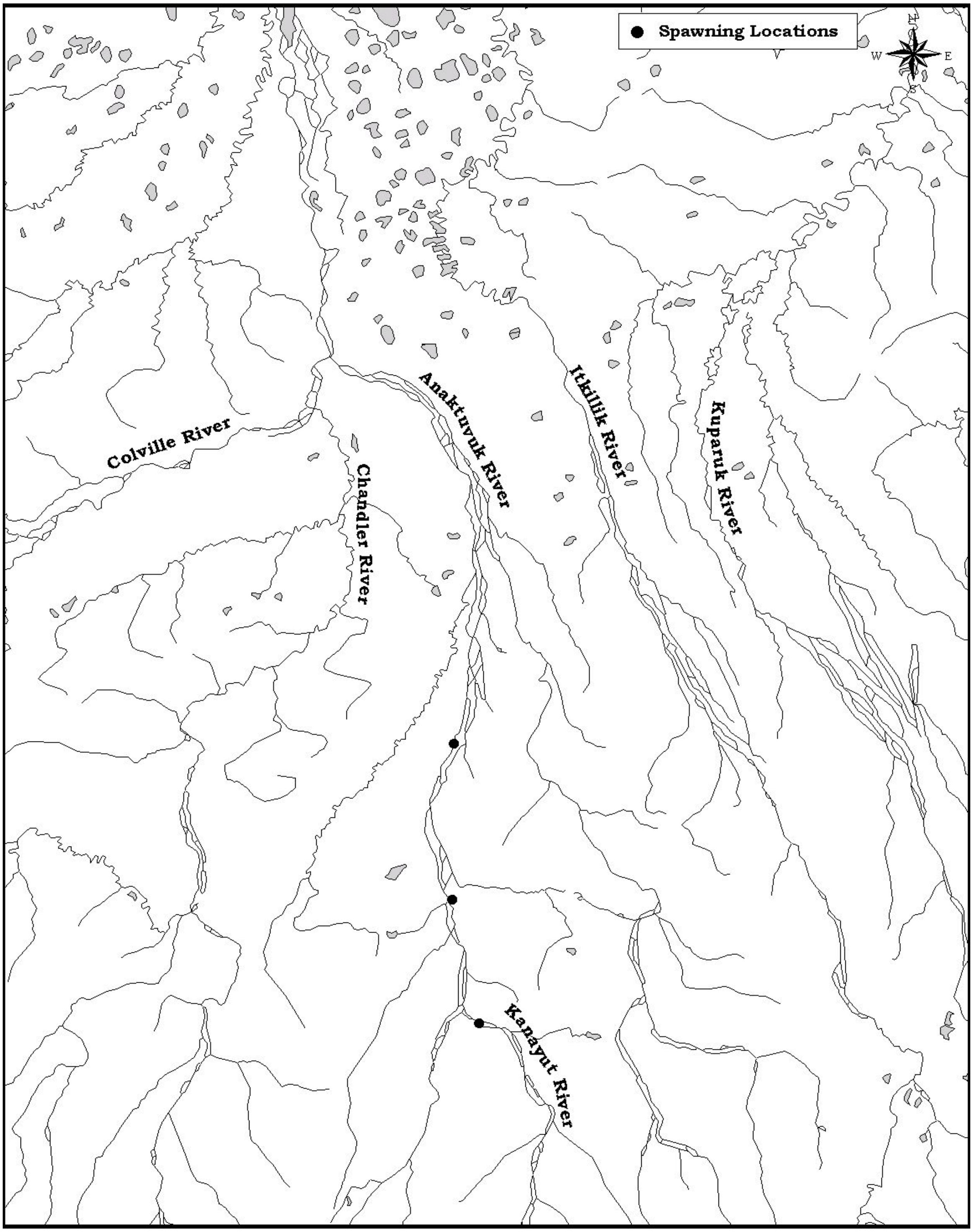

Figure 21.–Dolly Varden spawning locations in the Anaktuvuk and Kanayut rivers, September, 2002.

DISCUSSION

ABUNDANCE ESTIMATION

This study suggested that aerial surveys may provide a reasonable index of abundance for Dolly Varden in North Slope drainages over the range of fish densities and counting conditions encountered. Daily mean summed aerial counts made by the same observer had low variability and were repeatable within each year of the study. These aerial counts also accounted for a consistent proportion of population estimates obtained from mark-recapture experiments, with observers counting between 22% and 25% of estimated population.

In general, previous studies of aerial counts of Pacific salmon have indicated that variability increases with the density of fish being counted (Bevan 1961; Eicher 1953; Jones 1995). While there are only three years of data from this study, there did not appear to be a similar relationship for counts of Dolly Varden. In fact, the least variable counts were obtained during the year with greatest number of fish, although overall, variability was within a fairly narrow range all three years of the study, and was probably affected more by differences in counting conditions than by differences in fish abundance. It is also likely that the range of fish densities observed during this study was substantially lower than observed in studies of aerial counts involving salmon.

Aerial counts from 2001 and 2002 showed a similar pattern over time of increasing abundance in upriver sections and decreasing abundance in downriver sections over the period that replicate counts were made. This pattern was not apparent during 2003, and may have been related to a difference in the timing of migration into the overwintering area, since air temperatures were colder and river icing occurred earlier in 2003 than in either 2001 or 2002.

The average summed aerial count from 2003 was 50.3% of the same average summed aerial count from 2002, and only 24.9% of the same count from 2001. However, because the mark-recapture estimate for 2003 could only be obtained for Sections 1 and 2, comparisons between mark-recapture estimates and aerial counts for all sections in all years were not possible. However, the 2003 count for Sections 1 and 2 represented 23.6% of the mark-recapture abundance estimate from Sections 1 and 2, which was similar to the percent of the mark-recapture estimate accounted for by aerial surveys in 2002 (25%) and 2001 (22%; Table 4).

Taking into account the variability in both methods, the aerial surveys counted between 16% and 31% of the abundance as estimated by the mark recapture experiment during 2003. This compares to the 2002 aerial surveys that counted between 19% and 31% of the abundance as estimated by the 2002 mark recapture experiment, and the 2001 aerial counts that counted between 17% and 27% of the 2001 mark recapture estimate. These ranges represent the 95% confidence intervals for the ratios of the average aerial counts to the mark-recapture abundance estimates for each year calculated using the Delta method (Seber 1982). This proportion was relatively consistent over all three years, indicating that the aerial counts provided a valid index of abundance over the range of population densities encountered.

Both mark-recapture and aerial survey abundance estimates showed a large decline in overwintering abundance from 2001 through 2003, with estimates dropping by about half each year. The decline in the mark-recapture estimate between 2002 and 2003 is not directly comparable, since the 2003 mark-recapture estimate could only be conducted in Sections 1 and 2 due to weather problems. However, aerial survey counts also declined by approximately half between 2002 and 2003, and average aerial counts from Section 3 during 2003 accounted for only 20% of the total average count. Therefore, it is likely that if the mark-recapture estimate could have been conducted for all three sections in 2003, the total estimate would still have been much less than that obtained during 2002. It is possible that the abundance decline could have been due to increasing numbers of Dolly Varden reaching sexual maturity. This would have resulted in an increasing proportion of the total Sagavanirktok drainage overwintering population being recruited into spawning populations over the three years of this study. This illustrates the need to obtain information on abundance of spawners and stock composition of wintering aggregations in order to accurately assess Dolly Varden population status and trends.

While the relationship between each year's mark-recapture estimate and aerial survey count was similar, the variability of mark-recapture estimates was substantially higher than that for aerial survey counts (Table 4). While this suggests aerial survey counts were more precise, this study and past studies have shown that aerial observations tend to undercount numbers of fish and are thus not as accurate as mark-recapture estimates (Eicher 1953; Bevan 1961; Jones 1995; Bue et al. 1998). While biases in mark-recapture estimates could lead to either over or underestimating abundance, diagnostic testing of model assumptions indicated it was unlikely these estimates were substantially biased.

Radio tracking a small number of fish during mark-recapture experiments provided valuable information on fish movement. Dolly Varden captured in the lower sections of the index area and implanted with radio tags tended to move upstream during both 2001 and 2002. Upstream movement was consistent with information obtained from recapture histories during the mark-recapture experiment and with data from aerial counts. No fish initially captured and implanted with a radio-tagged within the index area moved upstream and stayed outside of the index area, including 10 fish implanted near the top of the index area in 2002. In addition, none of the 18 pre-spawning fish tagged upstream of the index area in 2003 migrated downstream into the index area during the time the mark–recapture experiment was conducted.

Any method of assessment of North Slope Dolly Varden populations must be conducted during a short time period because fish start migrating into overwintering areas in mid-August and appear to complete their migration by mid-September. Unfortunately, this time period typically includes the onset of winter conditions, which may preclude fish capture and make it difficult to operate boats. Because of this, traditional mark–recapture abundance procedures for Dolly Varden in North Slope drainages are not only expensive and difficult, but are also likely to fail occasionally due to winter weather.

Hydrologic regimes of North Slope drainages (low storage capacity of drainage basins and rapid runoff during rain events) combined with active braided floodplains mean that site, maintenance, and operations of weirs or counting towers is also difficult and subject to high failure rates. One alternative method of assessment that may have higher success is the use of new sonar technologies, but this method is still relatively expensive in comparison to aerial survey counts of overwintering aggregations.

Aerial counts as a population assessment method have a number of shortcomings. Counts can only be conducted when weather allows flying. The counts conducted for this study were done from a helicopter, and are probably not repeatable in a fixed-wing aircraft with the same level of precision. Counts may also vary depending on the presence and abundance of other fish species in the river. The proportion of the population counted is likely to be strongly influenced by the observers making the counts. Despite these drawbacks, results of this study show that carefully conducted aerial surveys can provide counts that reflect an index of true abundance for Dolly Varden in North Slope drainages,. This would make such surveys a valuable management tool that is cost effective relative to other assessment methods.

LENGTH COMPOSITION

Length composition information from four years for which Dolly Varden were sampled on the Ivishak River show the growth of what is probably two or three age classes through all four years of the study. The information also show recruitment of a new age class to the gear used during 2002 and 2003 (Figure 14). During 2000, very few fish captured were smaller than 350 mm FL, and none were smaller than 300 mm FL. During 2001, a low proportion of fish smaller than 300 mm FL appeared in samples, and this proportion increased in 2002 and 2003.

Because the same gear was fished in the same manner and locations in all years, these differences most likely reflect changes in the age composition of the overwintering aggregation rather than artifacts of variable gear selectivity

The length distribution of Dolly Varden in 2003 was more similar to that reported from the Ivishak River by Yoshihara (1972 and 1973) than length distributions from either 2000 or 2001. Samples collected by Yoshihara also were bimodal, with a small peak at 325 mm FL. The length distribution of 2002 and 2003 samples may have been affected not only by recruitment of first-year migrants, which spent their first year at sea, to the sampling gear, but also by the percentage of mature Dolly Varden that spawned in 2002 and 2003.

Because of the complex life history of Dolly Varden on the North Slope, it is very difficult to attribute changes in length distribution to any factor. The absence of apparent recruitment to sampling gear of a size class could be due to low spawning numbers of the parent year, low egg survival, low overwinter survival of pre-smolt juveniles, or low growth and marine survival of first-year out migrants. It could also be due to differences in the timing of migration into fresh water of different sized fish or differences in distribution in fresh water.

SPAWNING AND OVERWINTERING LOCATIONS

Spawning locations of Dolly Varden in most North Slope rivers appear to be widely dispersed, and primarily in the upper reaches of the drainages, within the foothills or mountains of the Brooks Range. In general, most spawning groups located consisted of less than 100 fish (based on aerial survey counts), and in many instances, consisted of groups of 50 fish or less (Appendix B). The timing of spawning appears to be quite variable from year to year in the same drainage. In the Ivishak, Ribdon, and Lupine rivers during 2001 and 2003, all fish observed on spawning locations after September 20 were still in pre-spawning condition. Fish were firm and would not express any eggs or milt, and no spawning behavior was observed. However, in the Ivishak and Ribdon rivers during 2002, all mature fish that were handled had already spawned by September 20. Fish observed and handled on the Kongakut River during 2000 were exhibiting spawning behavior and were in ripe condition on August 17.

The number of fish spawning in a given drainage and the number of sites used for spawning in a given year also appear to be quite variable. During 2002 and 2003, there were generally many more groups of spawners in the upper Ivishak River than in 2001, and these groups were distributed much farther upstream than in 2001. Also, in 2002 there were several groups that contained large numbers of spawners (over 200 fish). Abundance of fall-spawners in the

Saviukviayak, Ribdon and Lupine rivers during 2002 was substantially lower than in the Ivishak, Echooka, or Kavik rivers (Appendix B).

The distribution of spawners in the Anaktuvuk River during 2002 was significantly different than distributions observed in the drainages east of the Dalton Highway. The river was surveyed from the headwaters to near the confluence with the Colville River, and spawners were only located in three areas. Those locations were near the area where large numbers of overwintering fish were located. These areas were not in the upper reaches of the drainage, but at the northern extent of the foothills, near the beginning of the coastal plain.

Overwintering locations in the Ivishak River are widely dispersed, both within and below the index area. During both 2002 and 2003, approximately 25% of radio-tagged fish moved downstream of the locations they occupied in late September of the previous year,. In fall of 2001, six fish were radio-tagged above the index area, three at a spawning area in the upper Ivishak River, and three at a spawning area in the Saviukviayak River. During the spring of 2002, two fish in each drainage had remained above the main overwintering area (the index area), near the locations where they were radio-tagged (Figure 15). Of the 18 spawning condition fish radio-tagged in the upper Ivishak River in September 2003, all but one had moved downstream into or near the index area by May 2004 (Figure 17).

The distribution of overwintering fish observed during late-spring in the Anaktuvuk River was different than in the Ivishak River. Although only 23 radio tags were implanted in overwintering fish in September 2003, the 22 fish that were located in May, 2004 were all within approximately 5 km of their tagging site (Figure 18). This is probably related to differences in distribution of areas with groundwater upwelling between these two drainages. The Ivishak River has a very large area of active floodplain, whereas the overwintering area on the Anaktuvuk River appears to be centered around a single smaller area of groundwater input.

CONCLUSIONS

1. Aerial counts of overwintering Dolly Varden within a 28-km section of the Ivishak River conducted by the same observers had low variability, were repeatable over a range of abundances and conditions, and consistently represented 16% to 31% of the estimated abundance measured by mark-recapture methods.
2. The estimated abundance of overwintering Dolly Varden in the 28 km index area of the Ivishak River declined between 2001 and 2003 by approximately 70%.
3. The proportion of overwintering Dolly Varden that spawn in a given year, the timing of spawning, and the locations used for spawning on the Ivishak River appear to vary considerably from year to year.
4 Non-spawning anadromous Dolly Varden overwinter in the Ivishak River throughout approximately 50 km of stream, from the confluence of the Sagavanirktok upstream to approximately the confluence of the Ivishak and the Saviukviayak rivers. In addition, fish spawning in the Ivishak and Saviukviayak rivers may overwinter even higher in the drainages closer to the areas where they spawn. Overwintering habitat utilization is probably variable over time, due to shifting channel morphology and accompanying changes in groundwater sources.

RECOMMENDATIONS

1. Standardized aerial counts of overwintering aggregations of Dolly Varden in North Slope drainages conducted under similar conditions to this study can probably be used as a reliable index of overwintering abundance. However, these surveys should be combined with surveys of spawning areas in the same drainage, because the number of spawners among the total overwintering population seems highly variable from year to year. In addition, the performance of aerial counts should be assessed by performing independent estimates of total abundance, as was done in this study. This is particularly important for situations where information is critical to management.
2. The specific locations of critical spawning and overwintering habitat used by anadromous Dolly Varden in Beaufort Sea drainages may change greatly between years within a relatively large area of a drainage. Protection of such habitat should be based on locations determined over a relatively long period of time (e.g., 3-5 years).

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APPENDIX A

Appendix A.–Marking and recapture histories from 2001, 2002, and 2003 Ivishak River mark-recapture abundance experiments.

	2001 Mark-Recapture Estimate			Number Recaptured from Previous Event			
	Section	# Marked	# Examine	Sec 1 mark	Sec 2 mark	Sec 3 mark	Recaptures
	1	821	0	0	0	0	
	2	323	0	0	0	0	
	3	260	0	0	0	0	
				Marking Event			
Total Marked		**1,404**					
				Second Event			
Recap 1	1	0	950	16	11	0	27
Recap 1	2	0	475	0	2	10	12
Recap 1	3	0	126	0	0	4	4
Total Examined			**1,551**				
Total Recaptures							**43**
				Third Event			
Recap 2	1	0	324	2	3	0	5
Recap 2	2	0	30	0	0	0	0
Recap 2	3	0	52	0	0	1	1
Total Examined			**406**				
Total Recaptures							**6**

-continued-

Appendix A.–Page 2 of 2.

	2002 Mark-Recapture Estimate			Number Recaptured from Previous Event			
	Section	# Marked	# Examine	Sec 1 mark	Sec 2 mark	Sec 3 mark	Recaptures
			Marking Event				
	1	735	0	0	0	0	
	2	250	0	0	0	0	
	3	53	0	0	0	0	
Total Mark		**1,033**					
			First Recapture Event				
Recap 1	1	0	742	31	0	0	31
Recap 1	2	0	338	0	26	2	28
Recap 1	3	0	5	0	0	1	1
Total Examined			**1,085**				
Total Recaptures							**60**
			Second Recapture Event				
Recap 2	1	0	413	13	2	0	15
Total Examined			**413**				
Total Recaptures							**15**

	2003 Mark-Recapture Estimate			Number Recaptured from Previous Event			
	Section	# Marked	# Examine	Sec 1 mark	Sec 2 mark	Sec 3 mark	Recaptures
			Marking Event				
	1	568	0	0	0	0	
	2	181	0	0	0	0	
	3	106	0	0	0	0	
Total Mark		**855**					
			Recapture Event				
	1	0	531	38	3	0	41
	2	0	185	2	14	0	16
	3	0	0	-	-	-	-
Total Examined			**716**				
Total Recaptures							**57**

APPENDIX B

Appendix B.-North Slope Dolly Varden spawning locations.

River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
Kongakut	8/17/00	142	3	09	69	2	43	60
	8/17/00	141	59	54	69	4	45	75
	8/17/00	141	59	39	69	5	16	50
	8/17/00	141	58	46	69	5	44	90
	8/17/00	141	57	53	69	5	47	100
	8/17/00	141	56	55	69	6	06	40
Ivishak	9/24/00	147	43	04	69	2	04	120
	9/24/00	147	42	18	69	1	51	160
	9/24/00	147	35	57	69	2	32	85
	9/20/02	147	53	52	69	04	40	20
	9/20/02	147	52	88	69	03	82	40
	9/20/02	147	52	283	69	03	01	10
	9/20/02	147	55	61	69	05	97	10
	9/20/02	147	58	73	69	05	79	60
	9/20/02	147	59	22	69	05	76	110
	9/20/02	148	00	49	69	05	83	300
	9/20/02	147	52	10	69	02	98	15
	9/20/02	147	49	76	69	02	36	25
	9/20/02	147	48	64	69	02	25	135
	9/20/02	147	47	48	69	01	84	20
	9/20/02	147	43	17	69	02	04	125
	9/20/02	147	42	69	69	01	91	200
	9/20/02	147	48	12	69	02	23	30
	9/20/02	147	47	96	69	02	25	20
	9/20/02	147	40	320	69	01	91	50
	9/20/02	147	39	22	69	01	73	15
	9/20/02	147	20	96	69	01	13	35
	9/14/03	148	0	42	69	5	82	160
	9/14/03	147	55	23	69	4	98	12
	9/14/03	147	59	95	69	4	45	6

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River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
Ivishak	9/14/03	147	53	50	69	4	36	45
	9/14/03	147	52	45	69	3	23	25
	9/14/03	147	49	77	69	2	31	55
	9/14/03	147	49	3	69	2	21	125
	9/14/03	147	47	98	69	2	18	15
	9/14/03	147	48	36	69	2	19	15
	9/14/03	147	43	51	69	2	3	6
	9/14/03	147	43	14	69	1	97	130
	9/14/03	147	42	74	69	1	91	50
	9/14/03	147	42	61	69	1	86	60
	9/14/03	147	39	72	69	1	72	30
Ivishak	9/14/03	147	34	57	69	2	55	40
	9/14/03	147	34	57	69	2	55	6
	9/14/03	147	26	27	69	2	59	30
	9/14/03	147	24	24	69	2	3	9
	9/14/03	147	22	62	69	1	95	4
	9/14/03	147	22	39	69	1	91	30
	9/14/03	147	21	51	69	1	90	40
	9/14/03	147	21	25	69	1	55	10
	9/14/03	147	20	83	69	0	90	4
	9/14/03	147	14	52	68	57	39	44
	9/14/03	147	14	31	68	57	25	22
	9/14/03	147	14	2	68	57	19	10
	9/14/03	147	7	95	68	56	10	12
	9/14/03	147	7	67	68	56	3	10
	9/14/03	147	3	79	68	54	47	10
	9/14/03	146	59	66	68	53	30	30
	9/14/03	146	59	26	68	53	21	12
	9/14/03	146	51	24	68	52	25	27

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River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
Ivishak	9/14/03	146	50	91	68	52	16	6
	9/14/03	146	50	62	68	51	56	6
	9/14/03	146	50	27	68	51	36	8
	9/14/03	146	50	5	68	51	19	41
	9/14/03	146	49	12	68	51	2	13
Shaviovik	9/21/02	147	45	21	69	48	75	150
Echooka	9/19/01	147	59	80	69	24	42	40
	9/19/01	147	54	90	69	23	40	30
	9/19/01	147	50	96	69	23	16	40
	9/19/01	147	28	79	69	16	46	45
	9/19/01	147	30	16	69	16	98	50
	9/19/01	147	27	12	69	16	17	45
	9/19/01	147	24	85	69	16	09	50
	9/19/01	147	23	46	69	16	13	35
	9/20/01	147	22	83	69	16	07	150
	9/20/01	147	25	79	69	15	95	35
	9/20/01	147	19	89	69	15	65	50
	9/20/01	147	19	22	69	15	62	45
	9/20/01	147	12	72	69	11	62	40
Saviukviayak	9/16/01	148	01	07	69	03	19	35
	9/16/01	148	02	62	69	02	55	40
	9/16/01	148	07	90	68	57	22	35
	9/16/01	148	04	09	68	53	18	25
	9/19/02	148	08	36	68	59	77	40
	9/19/02	148	08	27	68	57	34	30
	9/19/02	148	09	25	68	58	69	15
	9/19/02	148	08	24	68	59	78	20

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River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
Saviukviayak	9/19/02	148	08	27	68	59	36	20
	9/16/03	148	7	6	68	55	57	10
	9/16/03	148	7	98	68	57	20	75
	9/16/03	148	8	35	68	59	86	50
	9/16/03	148	7	73	68	0	39	15
	9/16/03	148	6	98	68	0	62	10
Ribdon	9/17/02	147	48	73	68	39	34	50
	9/17/02	147	48	69	69	02	23	25
	9/17/02	148	16	42	68	38	38	25
	9/17/02	148	13	10	68	38	17	15
	9/17/03	147	48	99	68	39	27	10
	9/17/03	147	59	98	68	38	51	8
	9/17/03	148	16	64	68	38	42	10
	9/17/03	148	17	35	68	38	50	15
Lupine	9/18/02	148	14	54	68	52	41	20
	9/18/02	148	12	83	68	51	29	25
	9/18/02	148	14	54	68	52	41	35
	9/16/03	148	14	5	68	52	14	12
	9/16/03	148	12	97	68	51	38	7
Kavik	9/19/03	69	30	9	146	37	41	15
	9/19/03	69	28	47	146	36	36	10
	9/19/03	69	28	22	146	36	9	20
	9/19/03	69	27	97	146	35	88	15
	9/19/03	69	27	81	146	35	90	25
	9/19/03	69	25	73	146	34	45	35
	9/19/03	69	30	10	146	37	29	15
	9/19/03	69	30	19	146	37	12	80

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River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
Kavik	9/19/03	69	29	32	146	37	46	30
	9/19/03	69	31	87	146	38	1	30
	9/19/03	69	31	87	146	39	21	20
	9/19/03	69	32	34	146	39	33	25
	9/19/03	69	32	28	146	39	55	65
	9/19/03	69	33	29	146	39	75	50
Anaktuvuk	9/20/02	68	52	32	151	08	52	20
	9/20/02	69	03	17	151	07	02	35
Kanayut	9/20/02	68	43	68	151	4	67	35

APPENDIX C

Appendix C.-Ivishak and Anaktuvuk River Dolly Varden overwintering locations.

		Implant					Overwintering				
Frequency	River	Date	Location				Date	Location			
148.013	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	6.56	148	3.21
148.023	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	5.31	147	55.7
148.034	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	7.04	148	3.99
148.043	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	10.09	148	5.76
148.053	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	14.77	148	8.54
148.062	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	6.42	148	2.81
148.072	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	Fish not located			
148.083	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	6.56	148	3.21
148.093	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	19.82	148	12.66
148.103	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	7.21	148	1.84
148.114	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	12.8	148	5.07
148.124	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	17.49	148	8.98
148.134	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	12.78	148	5.01
148.144	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	24.23	148	14.53
148.153	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	6.46	148	3.18
148.163	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	24.23	148	14.53
148.174	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	7.11	148	4.28
148.184	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	6.31	148	2.3
148.194	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	24.4	148	15.46
148.204	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	10.05	148	5.15
148.213	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	11.9	148	5.12

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		Implant					Overwintering				
Frequency	River	Date	Location				Date	Location			
148.223	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	14.76	148	8.74
148.233	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	20.22	148	13.39
148.242	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	24.23	148	14.53
148.255	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	19.82	148	12.66
148.263	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	6.54	148	2.96
148.273	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	17.34	148	8.92
148.285	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	13.66	148	7.58
148.293	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	6.44	148	2.92
148.304	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	16.86	148	9.03
148.315	Ivishak	9/15/2001	68	57.23	148	7.9	4/16/2002	Fish not located			
148.323	Ivishak	9/15/2001	68	57.23	148	7.9	4/16/2002	69	3.24	148	1.10
148.334	Ivishak	9/15/2001	68	57.23	148	7.9	4/16/2002	69	1.9	148	4.83
148.344	Ivishak	9/15/2001	69	2.58	147	34.57	4/16/2002	69	2.42	147	36.5
148.354	Ivishak	9/15/2001	69	2.58	147	34.57	4/16/2002	69	6.51	148	3.18
148.362	Ivishak	9/15/2001	69	2.58	147	34.57	4/16/2002	69	2.04	147	25.72
148.374	Ivishak	9/15/2001	69	19.58	148	11.77	4/16/2002	69	25.07	148	17.1
148.384	Ivishak	9/15/2001	69	19.58	148	11.77	4/16/2002	69	8.51	148	5.27
148.393	Ivishak	9/15/2001	69	19.58	148	11.77	4/16/2002	69	19.04	148	10.77
148.404	Ivishak	9/15/2001	69	19.58	148	11.77	4/16/2002	69	13.18	148	5.97
148.423	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	17.82	148	8.99
148.433	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	14.43	148	8.00

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Frequency	River	Implant					Overwintering				
		Date	Location				Date	Location			
148.444	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	7.32	148	4.96
148.453	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	6.59	148	2.96
148.465	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	9.5	148	5.91
148.474	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	6.51	148	3.14
148.484	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	7.62	148	4.87
148.492	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	10.86	148	5.08
148.505	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	13.05	148	5.8
148.513	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	22.49	148	15.1
148.524	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	6.9	148	3.28
148.534	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	8.63	148	5.76
148.545	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	6.59	148	2.96
148.555	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	16.68	148	9.35
148.563	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	14.05	148	7.35
148.573	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	14.31	148	8.13
148.586	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	11.09	148	5.27
148.594	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	7.45	148	4.72
148.603	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	7	148	4.2
148.611	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	17.5	148	8.77
148.62	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	7	148	4.2
148.629	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	11	148	5.6
148.641	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	14.21	148	8.3

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Frequency	River	Implant					Overwintering				
		Date	Location				Date	Location			
148.652	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	9.06	148	6.02
148.660	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	9.48	148	5.9
148.668	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	13.23	148	5.63
148.682	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	10.97	148	6.15
148.690	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	17.5	148	8.77
148.700	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	7	148	4.2
148.711	Ivishak	9/15/2002	69	14.91	148	8.97			0		0
148.719	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	13.23	148	5.63
148.731	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	6.59	148	2.96
148.743	Ivishak	9/15/2002	69	19.58	148	11.77			0		0
148.751	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	22.27	148	14.87
148.760	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003		0		0
148.772	Ivishak	9/15/2002	69	19.58	148	11.77			0		0
148.780	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	14.21	148	8.3
148.790	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	8.95	148	6.02
148.810	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	6.73	148	3.4

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		Implant					Overwintering				
Frequency	River	Date	Location				Date	Location			
148.603	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
148.864	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	56.918	151	11.338
148.893	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
148.925	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
148.954	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.030	151	8.698
148.983	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	56.554	151	10.998
149.003	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68			
149.013	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
149.023	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
149.033	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
149.044	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	56.918	151	11.338
149.053	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	54.259	151	10.158
149.062	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
149.073	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
149.084	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	56.918	151	11.338
149.093	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	56.065	151	10.553
149.104	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
149.113	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
149.122	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	51.809	151	8.283
149.133	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833
149.252	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	51.809	151	8.283
149.263	Anaktuvuk	9/19/2003	68	54.76	151	09.42	5/5/2004	68	53.733	151	8.833

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		Implant					Overwintering				
Frequency	River	Date	Location				Date	Location			
149.143	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	5.329	147	57.097
149.153	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	18.152	148	9.117
149.164	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	8.730	148	5.443
149.171	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	6.598	148	2.387
149.184	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	2.526	147	33.847
149.193	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	17.980	148	9.149
149.203	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	11.448	148	5.518
149.212	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	5.317	147	56.944
149.234	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	5.978	148	0.796
149.244	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	7.562	148	3.914
149.272	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	11.834	148	4.963
149.283	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	7.562	148	3.914
149.293	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	18.008	148	9.296
149.302	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	6.615	148	3.262
149.312	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	27.091	148	24.650
149.324	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	17.384	148	9.169
149.334	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	9.442	148	5.752
149.344	Ivishak	9/20/2003	69	01.93	147	42.75	5/5/2004	69	9.076	148	4.832

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Frequency	River	Implant					Overwintering				
		Date	Location				Date	Location			
148.423	Ivishak	9/15/2002	69	6.36	148	2.39	5/5/2004	69	6.838	148	3.593
148.513	Ivishak	9/15/2002	69	6.36	148	2.39	5/5/2004	69	13.940	148	6.757
148.534	Ivishak	9/15/2002	69	10.57	148	6.1	5/5/2004	69	8.072	148	4.094
148.563	Ivishak	9/15/2002	69	10.57	148	6.1	5/5/2004	69	20.999	148	13.078
148.594	Ivishak	9/15/2002	69	12.46	148	4.81	5/5/2004	69	7.163	148	2.981
148.611	Ivishak	9/15/2002	69	12.46	148	4.81	5/5/2004	69	19.864	148	11.185
148.641	Ivishak	9/15/2002	69	14.91	148	8.97	5/5/2004	69	17.862	148	8.200
148.652	Ivishak	9/15/2002	69	14.91	148	8.97	5/5/2004	69	2.159	147	47.412
148.660	Ivishak	9/15/2002	69	14.91	148	8.97	5/5/2004	69	15.332	148	7.805
148.700	Ivishak	9/15/2002	69	14.91	148	8.97	5/5/2004	69	6.545	148	1.739
148.719	Ivishak	9/15/2002	69	19.58	148	11.77	5/5/2004	69	16.057	148	8.897
148.731	Ivishak	9/15/2002	69	19.58	148	11.77	5/5/2004	69	6.545	148	1.739
148.772	Ivishak	9/15/2002	69	19.58	148	11.77	5/5/2004	69	18.793	148	10.156
148.810	Ivishak	9/15/2002	69	19.58	148	11.77	5/5/2004	69	24.891	148	16.339